Digitized by the Internet Archive
in 2013

http://archive.org/details/publicroads03offi

AGRICULTURAL REFERENCE DEPARTMENT
CLEMSON COLLEGE LIBRARY

U.S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 25 WASHINGTON, D. C. MAY, 1920

A SPRING-TIME ROAD NEAR DELAWARE WATER GAP

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page

Bituminous Surface Treated Macadam and Gravel Roads 3
J. F. Witt

Winter Road Work in the Dakotas, Minnesota and Wisconsin 7
E. C. Edwards

7,564,846 Motor Vehicles in the United States 11
A. P. Anderson

Federal Control of Bridges Over Our Navigable Streams 20
G. B. Pillsbury

Asphalt Content of Road Oils 23
B. A. Anderton and D. G. Taylor

Galvanized Culverts 26
L. G. Carmick

Federal-Aid Allowances 29

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer

BITUMINOUS SURFACE TREATED MACADAM AND GRAVEL ROADS

By J. F. Witt, Mem. Am. Soc. C. E., Dallas, Tex.

OLD GRAVEL ROAD SURFACE TREATED WITH AN 80 PER CENT ASPHALTIC ROAD OIL. PHOTOGRAPH MADE TWO YEARS AFTER TREATMENT.

THE problems of selecting a type of surfacing for a highway, considering all the elements of amount and type of traffic, amount of money available, and the kinds of material which can be secured at various prices, has always been one of the most perplexing problems with which highway engineers have been required to deal. The vast sums which have lately been appropriated for construction all over the country have added greatly to the responsibility of engineers, and have made it more important than ever that careful consideration be given to all factors involved in selecting the surfacing material.

If it were practicable the easiest solution would be to select one of the expensive and durable types, such as brick, or concrete, or bituminous concrete, for all roads; but there are few States and fewer counties that can afford the outlay of money that would be necessary to construct all roads of these expensive materials. One of these expensive types will, of course, be decided upon for the more important heavy traffic roads, but the problem of what surface to select for the large mileage of less important roads is not so easily disposed of. To use the natural materials close at hand, such as gravel, or shell, or sand-clay, is an expedient which results in low first cost, but such materials are unsatisfactory from a traffic standpoint, and are a constant source of annoyance and expense.

THE HAPPY MEDIUM IN COST.

Having put aside the most and the least expensive materials, the only recourse is to look to the "happy medium" in cost and wearing value for a large part of

206323

the mileage contemplated. This takes us at once to the "bituminous surface treated" roadway. Plain water-bound macadam is a failure in this country at any rate. We are told that is it successfully used in France, but in this country we have learned by costly experience that the water-bound macadam surface is no match for the automobile and the motor truck.

By treating the surface of a properly constructed water-bound macadam or gravel road with suitable bituminous material, however, the writer has found that a surface may be built up which is entirely adequate for the large mileage of roads of intermediate importance which forms a part of every State and county system. For a number of years he has constructed roads of this character in Dallas County, Tex., and the manner in which they have withstood the effects of moderately heavy traffic has convinced him that there is real merit in this type of construction.

ON WATER-BOUND MACADAM ROAD.

The macadam should be constructed according to modern specifications of sufficient depth to prevent "breaking down" of the mechanical bond under the heaviest loads contemplated. An essential factor of this requirement is a good grade of crushed stone. There is a certain but indeterminate "thrust" at the edges of the macadam surface under loading; and as the ordinary macadam has only earth shoulders to protect its edges, a weakening of the entire structure is often the result of traffic. The use of any good type of curb is usually considered to be prohibitive in cost; but a good substitute can be constructed at moderate cost by treating the outer 12 inches on each side of the macadam with bitumen applied by the "penetration method," using 1 gallon per square yard on the base course and 1 gallon per square yard on the surface course of stone. This can be done at a cost of approximately 10 cents per linear foot of road, or approximately $530 per mile. The benefits are fully worth the investment.

When the macadam surface is finished and screenings and dust have been used to fill the voids of the body of the macadam and to fill the interstices and bond the surface, a "glazed" surface usually results after the finished rolling and especially after the road has been thrown open to traffic for a few days. Some engineers specify that the bitumen shall not be applied until such time as the traffic has prepared the surface by wearing the glaze away. The writer has tried this method and found that the traffic does not wear the surface uniformly. If the treatment is applied when that part of the road used by traffic is ready, the outer edges of the macadam will still retain the glaze, while if it is delayed until the entire surface is freed from the glaze, the center, or most heavily traveled section, will have begun to ravel, thus weakening the structure.

PREPARING FOR THE BITUMEN.

It is better to keep the traffic off the roadway until after the bitumen has been applied. Before the application of the bitumen the glaze should be removed by sweeping with either wire or fiber, mechanical or hand, brooms. The job can not be properly done, however, without the use of hand brooms. A combination of the two works economically and well. But whatever method is employed the sweeping should be done with care, so that the loose flaky material and foreign matter may be removed without loosening the mechanical bond of the surface stones.

After sweeping, the surface should be flushed with water, using a pressure-flushing tank. Whether the stone surface should be damp or dry when the bitumen is applied is open to question. The writer prefers a dry surface, although in making some tests during 1917 he found the adhesion of the surface mat to damp surfaces to be as good as to those which were dry; even to wet surfaces the adhesion was very good. In the tests 12-inch square concrete blocks were used. Twelve sets of specimens were prepared, each set being made of three specimens, one wet, one damp, and one with a dry surface. Space can not be given here to record the results of the tests made but, as stated, they did not change the writer's preference for a dry surface.

APPLYING THE BITUMEN.

After the surface has dried sufficiently the bitumen should be spread in two applications by a pressure distributor and the mineral covering should be spread to a depth of approximately one-half inch, not earlier than 2 minutes, nor, if practicable, not later than 20 minutes, after the heavier bitumen is applied. There is no rolling after the bitumen is applied. The surface is completed with the application of the mineral covering and is left to the traffic to iron out.

Bitumen should not be applied when the open-air temperature is below 60° F. and its consistency should be as follows:

If using asphalt: First treatment—Asphaltic road oil minimum of 55 per cent asphalt of 100 penetration. Viscosity (Engler) 50 c. c. at 60° C., 100–250 seconds. Second treatment—86 per cent asphaltic road oil. Viscosity (Engler) 50 c. c. at 100° C., 555–755 seconds.

If using coal-tar derivatives: First treatment—Specific gravity at 60° F., 1.14–1.18. Viscosity (Engler) 100 c. c. at 104° F., 125–225 seconds. Free carbon not less than 4 per cent nor more than 12 per cent. Second treatment—Specific gravity at 60° F., 1.20–1.26. Vicosity (Engler) 100 c. c. at 212° F., 125–200 seconds. Free carbon not less than 12 per cent nor more than 22 per cent.

First application of bitumen to be at the rate of 0.2 gallon per square yard.

Second application of bitumen to be at the rate of .03 gallon per square yard.

BITUMINOUS TREATED WATER-BOUND MACADAM ROAD IN TEXAS. PHOTOGRAPH TAKEN THREE YEARS AFTER CONSTRUCTION.

Using tar for the first treatment and asphalt for the second treatment produces splendid results.

The mineral covering should be graded from one-half inch in size down to dust. The run of the crusher may be used, except that dust passing a 30-mesh sieve should not exceed 15 per cent. The surface crown should be about 0.3 inch per foot.

GRAVEL WITH BITUMINOUS SURFACE.

After the first-class gravel road has had traffic sufficient to form a hard crust, the surface should be swept or water flushed until it is practically free from loose particles or foreign matter. The bitumen should then be applied in two courses in the same manner as for water-bound macadam.

Gravel should be used for covering material, and it should be clean, sharp, and well graded from 1 inch down to sand. The sand passing a No. 30 sieve should not exceed 30 per cent. A roller should be used on this covering to make sure the larger pebbles are securely bedded: after which the road should be opened to traffic.

All breaks which develop in the surface during a period of from three to five months after the road is opened to traffic should be repaired at once by a maintenance gang, equipped with a heating kettle and pouring pots; and at the end of this period the surface should be scarified for a depth of from 1 to 1½ inches.

By then disk-harrowing the scarified material, reducing it to a mealy condition, the bitumen content will be distributed uniformly throughout the depth scarified. Dress this material with the grader blader and roll it thoroughly; follow the rolling immediately with an application of one-half gallon per square yard, using the bitumen specified for "second treatment"; cover as before, with gravel, and roll, and the road is ready for traffic.

CRUSHED STONE TOP TO GRAVEL.

All this work subsequent to the first opening of the road to traffic may be avoided with splendid results, if a good quantity of crushed stone be used in sufficient amount to top the gravel with a "binder course" of stone to a depth of from 2 to 4 inches. The greater

the depth of this "binder course," the better will be the results obtained. The stone and gravel foundation should be wet and should be rolled until the stone is imbedded in the gravel surface to a depth of approximately an inch. Such a road treated with bitumen as described for water-bound macadam, will be almost as satisfactory as an all-rock road, and can be used to advantage where crushed rock is costly and gravel reasonably cheap. The crown for the gravel or gravel and rock roads should be about three-eighths of an inch per foot.

The photographs show sections of roads constructed by the writer after the manner described in this article. The first is a view of a surface-treated water-bound macadam road constructed in March, 1917. The photograph was taken in March, 1920, three years after construction, and up to that time there had been no expense for maintenance. The bituminous material used in the first application was a light coal tar, applied at the rate of 0.3 gallon per square yard; the second application was made at the rate of 0.3 gallon per square yard, and a heavier coal tar was used. The mineral covering was trap rock, of a maximum size of one-half inch and the minimum size little larger than dust. This road has withstood a traffic of 1,500 vehicles per day, of which 90 per cent have been automobiles, 5 per cent horse-drawn vehicles, and 5 per cent motor trucks.

The second picture shows the result of surface-treating an old gravel surface with an 80 per cent asphaltic road oil in November, 1918. The photograph was taken in March, 1920, and up to that time there had been no expense for maintenance. The mineral covering in this case was a clean, sharp gravel, ranging in size from 1 inch down to sand, of which there was about 40 per cent. This road has carried a traffic of 800 vehicles per day, of which 90 per cent were automobiles, 5 per cent were horse-drawn vehicles, and 5 per cent were motor-trucks.

MISSISSIPPI RIVER SCENIC ROAD.

Road District No. 1, composed of five wards in the Parish of West Feliciana, La., has voted $250,000 worth of 5 per cent, 40-year bonds, to be supplemented by United States Government aid to the amount of $200,000.

They propose to build 42 miles of standard gravel highway under the supervision of the State highway department and the United States Government, which will form a link in the great Mississippi River scenic highway from St. Paul to New Orleans.

GOVERNMENT SAVINGS STAMPS.

Regardless of temporary betterments in the price situation, such as the recent price-cutting wave which swept the country, the high cost of living will not permanently cease to be until production much more nearly overtakes consumption than it does now.

Speakers at a recent meeting of the Economic Club in New York City said that only a new orgy of spending and no permanent betterment to the price situation have resulted from the recent cut-price sales throughout the country. Were price cuts the result of increase in production, these leaders say, such cuts would reflect changed conditions which would mean that prices had taken a step toward a permanent return to lower levels. Instead of this, it was urged, the recent price cuts were caused solely by the exigencies in which merchants found themselves because of a cessation of buying by the public and questions involved in the financing of their business.

J. I. Straus, of R. H. Macy & Co., was the speaker at the Economic Club dinner who analyzed the results of the price-cutting movement.

"The horizontal cuts, if they continue, will seriously menace the prosperity of the industry concerned," he said. "If the reductions are legitimately made, they are not only causing a sacrifice of reasonable profits, but are cutting into capital; if they are falsely made, they are misleading the public into unwise extravagance.

"As manufacturers have all along complained of the inability to deliver requirements, the rehabilitation of merchandise stocks, depleted by forced sales, will create an additional demand, and, therefore, will tend to cause a rise in prices. In other words, the distributors are bulling the market against themselves."

Mr. Straus urged the decreasing of demand through voluntary self-denial and the restriction of exports by a licensing system.

Francis H. Sisson, vice president of the Guaranty Trust Co., said:

"The advantages accruing to consumers in consequence of declining prices were easily exaggerated and misunderstood. As the reductions in prices at the present are not due to overproduction," he said, "it would seem advisable to avoid a hasty conclusion that the present movement forecasts a universal and drastic drop in commodity prices."

The need, therefore, for continued saving and safe investment remains paramount. The present market prices of Liberty bonds and Victory notes, as well as the continuation of the sale of Government savings securities, offer the public the opportunity to invest their savings so as to obtain positive and assured returns.

—BUY W. S. S.—

WINTER ROAD WORK IN THE DAKOTAS, MINNESOTA, AND WISCONSIN A SUCCESS.

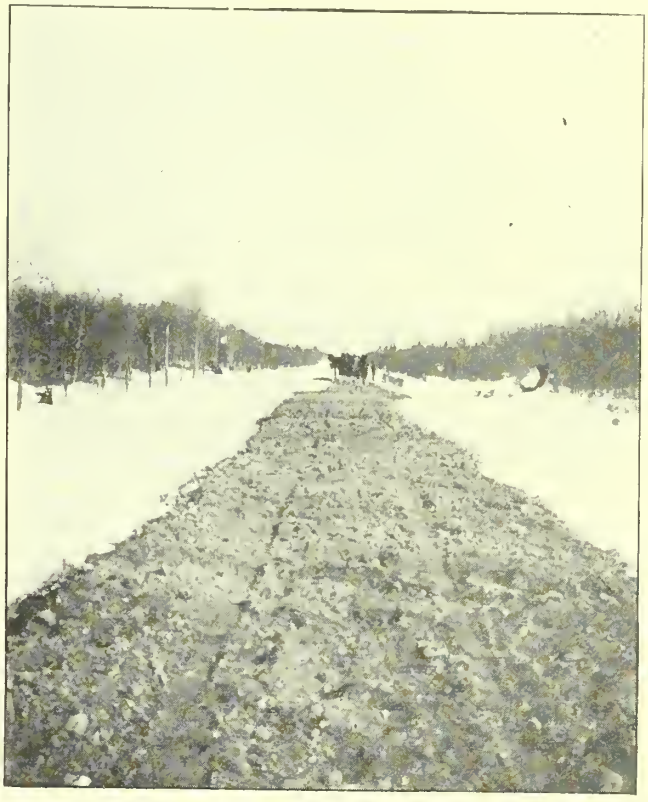
By E. G. Edwards, Highway Engineer, Bureau of Public Roads.

WINTER-road work, consisting mainly of hauling gravel for surfacing, has been carried on for several years past in some of the counties of northern Wisconsin. The advantages obtained here are (1) the greater accessibility of the pits in winter; (2) the larger number of teams available, and (3) lengthening of the construction period.

With the ground frozen it is possible to haul across swamps and streams, as well as over sandy soils and woods roads with sleds where summer hauling with teams and wagons would be impossible. A material reduction in the length of haul is often secured and a better selection of material is possible.

The yardage which can be hauled is much greater per team, varying from 3 to 6 cubic yards to the load for one team and from 5 to 8 yards where four horses are used, the variation being due to road and weather conditions.

In farming communities it is hard to secure teams for road work during the summer months. During the winter months, however, a great many farm teams represent such an expense that the owners welcome an opportunity for putting them to work. Then, too, the contractor, or the county, where work is done by force account, is able, through carrying on this winter hauling, to retain the best men and promote efficient organization.



GRAVEL SURFACING PLACED IN WINTER, OCONTO COUNTY, WIS.

PREPARATION AND EQUIPMENT.

For good results preparation should be made in the fall for the winter's work. The pits should be stripped and approaches prepared before the ground freezes. Hauling should begin, where this is practicable, as soon as the ground freezes, using wagons until there is enough snow for sleds. Hauling should be continuous, to maintain a solid roadbed for the sleds, as where the snow is packed hard after each fall the track holds up better during the periods of thaw.

As a 7-yard load of gravel weighs something over 10 tons, a runner 3 inches wide, with a bearing length of 6 feet, or about 8 feet long, including the rise, is required. Using smaller runners on a well-maintained snow road is a mistake, as the hauling capacity of the teams is materially reduced.

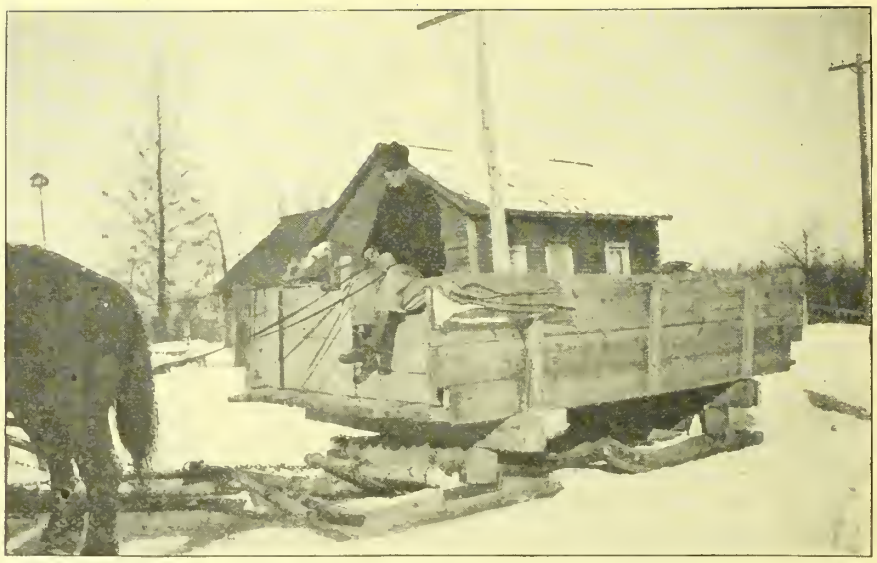
Logging sleds which have been cut down from a 6 foot 8 inch to a 4 foot 6 inch gauge are commonly used. My observations lead to the belief that cutting down the gauge is a mistake. I have observed logging teams hauling 15-ton loads on 6 foot 8 inch gauge sleds with less effort than that required to haul 8 or 9 tons of gravel on similar sleds with the narrow gauge. This is accounted for by the fact that where

WINTER ROAD WORK IN MINNESOTA. LOADING SLEIGHS BY TRAPS ON MARSHALL COUNTY PROJECT.

the wide gauge is used the track is never cut up by the horses' feet. It always gives a smooth, clean bearing on the full length of the runner, while the horses cut up the track for the sled of the narrow gauge.

Icing the track is practiced to some extent. For this purpose a tank mounted on a sled is used. A properly regulated stream of water is allowed to run from the rear of the tank into each of the tracks as the team hauls it along the road. With the 6 foot by 8 inch gauge very little renewal work is required, once the groove has been well iced.

The boxes for hauling the gravel vary from 4.5 feet to 7 feet in width and from 2 feet to 4 feet in depth, with a usual length of 12 feet. The loose planks forming the bottom are usually 3 inches thick and from 3 inches to 8 inches wide, the narrower plank being easier to manipulate in dumping. In some cases it is necessary to uncouple the sled and haul the front and rear sections out separately after dumping the gravel.



HAULING GRAVEL IN WINTER FOR ROAD WORK. LOAD OF SIX CUBIC YARDS HAULED BY TWO TEAMS 7½ MILES, OVER GRADES UP TO 6 PER CENT.

REMOVING SNOW.

Where the road has been graded the previous season, as is usually the case, the snow is cleared away by the use of a blade grader and hand shoveling, for a width about 4 feet less than the required width of surfacing. The full amount of gravel is then deposited and the gravel strip is widened and shaped to the proper cross section in the spring after the frost is out.

Where the frost goes out gradually the shoulders of the road first thaw out. The frozen road underneath the gravel thaws out more slowly and drains out through the shoulders. This leaves the road in good condition for shaping up with a road machine. In case of warm rains, coming before the road thaws out, however, the frost may be drawn from the subgrade under the gravel before the shoulders thaw out. In this case more time and labor is required to get the road into shape. The cost of shaping the gravel on the road in the spring averages about 10 cents per cubic yard.

Where the gravel is hauled before the grading is done it is stock-piled, usually at the rate of 8 to 10 piles per mile, care being taken to place the piles where the gravel will be easy of access and not interfere with the construction work. Rehandling from the stock piles to the road costs about 35 cents per cubic yard.

LOADING AT THE PIT.

Methods used for loading at the pit are practically the same as in summer. Hand loading, teams and scrapers with a trap and elevators with bins are commonly used.

The cost of loading runs from 35 cents to 45 cents per cubic yard. Spreading costs from 10 cents to 20 cents. The cost of hauling depends upon the weather to a considerable extent, as light loads must be hauled during and for a day or two after each stormy period.

The average cost where the haul is from 4 to 7 miles runs from 20 cents to 30 cents per mile per cubic yard. These prices are based on $4 per day for labor and from $7.50 to $10 per day for man and team.

At Neillsville, Clark County, Wis., disintegrated granite is taken from a quarry where some blasting is required. Here the cost of drilling, blasting, and loading is about $1 per cubic yard. The cost of an average 5-mile haul to stock piles is about $1.60 and the cost of the placing and spreading to be done later is estimated at 40 cents, making the total cost of material in the job $3 per cubic yard.

On Federal-aid project No. 20, Goodhue County, Minn., 4.5 yards were hauled on two wagons, pulled by a 6-horse team, handled by one teamster. The cost of this was 95 cents per yard for loading and hauling the first mile, and 50 cents per yard per mile for additional haul, based on $4.50 per day for labor and $3 per day for teams. During the summer it is impossible to haul more than 1.5 yards on a wagon due to sandy roads.

HEAVY TRUCKS ON FROZEN ROADWAY.

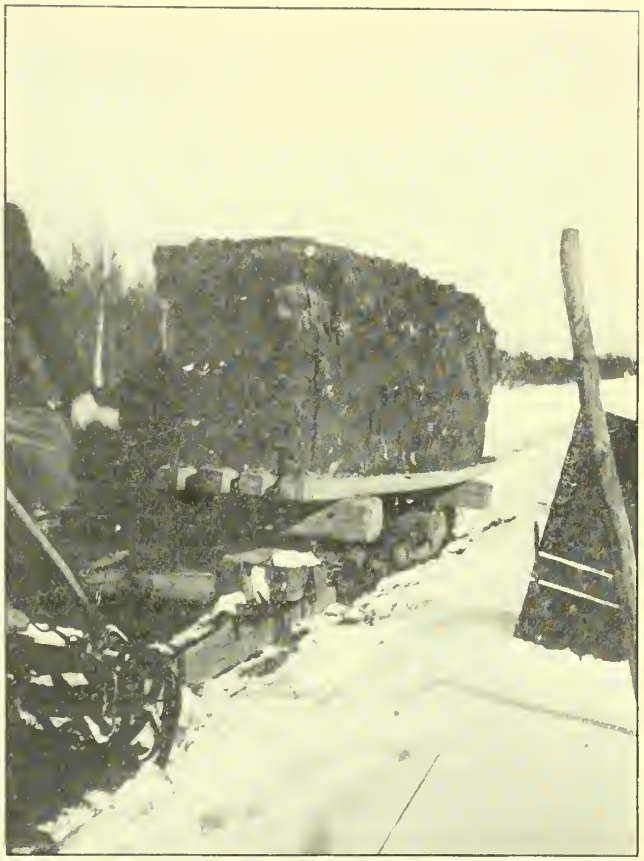
On project No. 54, Lac qui Parle County, Minn., steam shovel outfits were used to load gravel hauled by trucks of 5-yard capacity. The roads were practically clear of snow and the hauling was done both rapidly and economically over the frozen earth. It

would have been impossible to use heavy trucks on this work during the summer months, and considerable lost time would have been inevitable in using teams and wagons or light trucks.

On project No. 55, in the same county, an outfit of ten 1½-yard trucks, with pneumatic tires with an average haul of 3 miles, made a very good record. The loading was done by hand shoveling, five extra shovelers working at the pit, with the truck drivers helping to load. The drivers were paid by the yard according to the length of haul, and they averaged 20 yards per day on the average haul of 3 miles. The contract price on both these projects was 95 cents for loading and hauling the first mile, and 48 cents per mile thereafter. Both of these projects are in a heavy clay loam soil where it is practically impossible to haul loads over the dirt roads during wet weather.

In Marshall County, Minn., on a section of swamp road, the peat was used to build up the grade about 3 feet above the swamp. By the use of a disk harrow and a 10-ton roller the peat was compacted into a fairly sound roadbed, which enabled hauling by wagons in the fall before the snow came. As soon as there was enough snow the hauling was done on sleds, 3½ yards to the load, the output per team being more than doubled.

On Federal-aid project No. 12, in Minnehaha County, S. Dak., gravel was hauled by mule teams and dump wagons. Twenty teams were used in the hauling and they made six trips in a 10-hour day on a 2-mile haul. The loading was done through a trap, by teams and fresno scrapers. Extra teams were used to double up on hills between the pit and the road. This contractor had 13 Ford trucks with 1¼-yard dump bodies, which were loaded by a steam shovel and as there was very little snow during the winter of 1919–20 they gave very satisfactory service in getting the gravel onto the road.



UNLOADING 7-YARD SLEIGH LOAD OF GRAVEL, FEDERAL-AID PROJECT 85, OCONTO COUNTY, WIS.

WINTER HAULING HAS ADVANTAGES.

From the writer's observations, based on work inspected and data obtained during the winter of 1919–20, the conclusion is warranted that winter hauling of surfacing materials offers substantial advantages where conditions are favorable and when properly planned and handled.

Where the hauling can be done on sleds each team can haul at least double the quantity possible on wagons, even over roads where summer hauling on wagons is practicable.

During the summer and fall of 1919 in western Minnesota and the Dakotas, where gravel hauling on heavy trucks and with wagons of large capacity, drawn by tractors, was attempted, serious damage to the subgrade and much delay due to rainy weather invariably occurred.

On the other hand, with the subgrade once shaped and frozen solid the heavy trucks, loaded by steam shovels, were able to operate at full capacity without hindrance to traffic or damage to the road, during the entire winter.

RENCHING OUT SNOW BY ROAD MACHINE AND TEAM, KEWANEE COUNTY, WIS., FEBRUARY 28, 1920.

In many instances the contractor is barely able to finish the grading by the time for freezing up in the fall. The newly graded road, unless the gravel surfacing can be placed during the winter, is in poor condition for traffic in the spring, and the maintenance work absolutely necessary to keep the dirt grade in shape for traffic is usually much greater than is required in maintaining and reshaping the gravel surfacing while it is being compacted by the traffic.

IOWA TRIES OUT UNIQUE ROAD BUILDING EXPERIMENT.

Iowa's unique 1919 road building experiment, in which two independent individual contractor's outfits were hired with which to build the Montgomery County Federal Aid road, instead of contracting for the construction of the road with the contractors, has proven so promising in its preliminary tryout that this year five separate complete outfits have been hired and put to work in order to rush completion. The job is unique in that so far as the State, Federal, and county officials concerned know, it is the first and only one in which such a system has been tried out.

The experiment is an effort to find out under actual working conditions what it costs, under fair average conditions, to do road grading work and incidentally to have some definite and reliable basis upon which to approve or disapprove prices on such work offered by contractors at road lettings.

For a considerable time before the work was undertaken last year, bids received on road grading work ranging as high as 55½ to 60 cents per yard had been considered by the commission to be too high. When in July the low bid on the 216,000 cubic yard job of earth moving in Montgomery County was found to be 55 cents, the State and county officials decided to reject all bids and make a counter proposition to the two low contractors. The proposition was to hire their entire outfits and equipment, owners included, for a stipulated sum. The commission agreed to pay all labor hire, all bills for groceries and provisions, horse feed, and repairs to all equipment except harness. The contractors were each required to give their entire time to the management of their own outfits under constant direction of the commission resident engineer.

The work started on July 20. Good weather and good working conditions enabled the crews to make an unusually low record for the first few weeks, dirt being moved for as low an average as 30 cents. Later more difficult work was encountered. Work in the hills in the vicinity of the Nodaway River became very expensive. Sand had to be removed for long stretches and earth filled in to build up the grade. There was a great deal of grubbing, removal of trees and stumps. Over 2,500 sticks of dynamite were used. A blasting gang was kept busy during almost the entire working time. There was one 13-foot cut and one 16-foot fill. By the end of the working season the most difficult work of the entire job had been completed. Eighty thousand cubic yards of earth had been moved at a cost of $40,978.56, or an average of 52 cents per yard. The figures up to this point in a way justified the bids by the contractors of 55½ cents at the letting.

Last year there were two outfits. Each had an 18-team elevating grader outfit. Three more similar outfits have been contracted for this season, and at present the five outfits are all at work. The job was, so far as known, the first large Federal-aid job to get under way in the State this year. With the great advance in prices for labor, supplies, and food, the engineers in charge, it is feared, will have a difficult time holding the cost down to the last year's figures. However, the most expensive work has been completed. What remains is comparatively easy excavation and reasonably short hauls. With an early start with the five outfits with their hundred head of horses and mules, their 75 or 80 men, and equipment, all in good shape as a result of careful overhauling during the winter, the work will be rushed to completion just as quickly as possible. Incidentally, carrying the job over into the 1920 season will give an opportunity to find out what work is going to cost under this season's working conditions and form a reliable standard upon which to pass judgment upon 1920 grading prices. The figures obtained up to the close of work last season of 52 cents per cubic yard in a way justified the low price bid at the letting of 55½ cents. It is hoped, however, even under present conditions, to lower this average somewhat and show a substantial saving. Incidentally, it will be a matter of satisfaction to have at hand actual cost data on earth excavation and road grading on a job of such magnitude as a basis upon which to approve or disapprove bids offered by contractors at road lettings.

MARYLAND PROTECTS CONTRACTORS.

Reducing risks on highway construction has been the subject of communication between the Associated General Contractors and highway officials of the States. Replies from 40 States to a recent letter urging the insertion of a clause in their contracts protecting contractors against increase in freight rates, showed that 18 States had adopted or promised to adopt the clause and 13 have the matter under consideration. A letter from Mr. John N. Mackall, chief engineer, Maryland State Roads Commission, states that Maryland has also included the provision in highway contracts, the following clause having been added:

The bidder in naming his price for items requiring transportation of materials on common carriers, will base it on the prevailing rate of freight at the date of the opening of the bids. Should there be an increase in freight rates, the contractor will be allowed compensation for such increase.

7,565,446 MOTOR VEHICLES IN U. S.

Registrations, Licenses, and Revenues in the United States During the Calendar Year 1919.

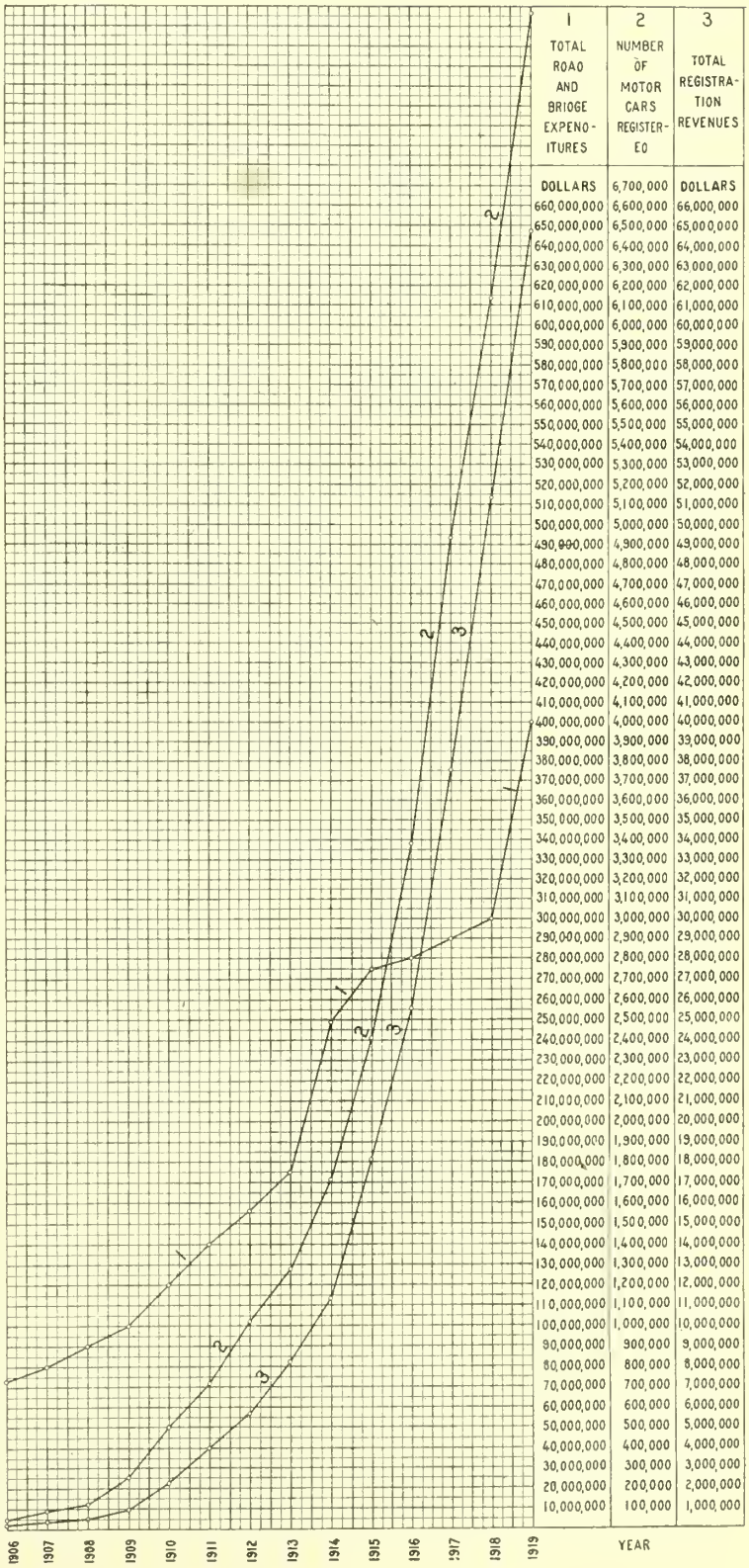
By Andrew P. Anderson, Highway Engineer, Bureau of Public Roads.

A TOTAL of 7,565,446 motor cars, including commercial vehicles, and 241,038 motor cycles were registered in 1919 in the 48 States and the District of Columbia. The registration and license fees, including those for chauffeurs, operators, and dealers, amounted to a total of $64,697,255.58.

As compared with 1918, the data for 1919 represents an increase of 23 per cent, or 1,418,829 motor cars. This increase alone represents about 10 per cent more cars than the total number registered in the United States during the calendar year 1913. In this connection it is interesting to note that the number of cars registered during 1919 in the two States of New York and Pennsylvania exceeded the total number of cars registered in the entire United States in 1912, while the revenues derived from the New York and Pennsylvania registrations during 1919 were about double those derived from all motor-vehicle registrations and licenses in the entire United States in 1912. The revenues derived from all registrations and licenses during the year 1919 exceed those of 1918 by 20 per cent, or a total of $13,219,838.97. In 1914 the total gross revenues collected amounted to only $12,381,951.

INCREASE IN A DOZEN YEARS.

The increase in motor-car registrations and revenues in the United States during the past dozen years presents many interesting comparisons. This is especially true in respect to the use made of the revenues. In 1906 the total registrations were approximately 48,000 cars, paying a gross revenue of about $193,000, or slightly more than that collected during 1919 by the State of Arizona. Furthermore, in 1906 the gross registration revenues were equivalent to less than three-tenths of 1 per cent of the total rural road and bridge expenditures for that year. In 1919 the motor-vehicle revenues represented approximately 16 per cent of the total road and bridge expenditures for the year. Furthermore, while in 1906 practcally none of the motor-vehicle revenues were applied to road maintenance and construction, in 1919 over 92 per cent of the gross returns, or $59,907,136.18, were devoted to this purpose, and of the total amount applied to road work, 70 per cent, or $42,492,604.17, was expended more or less directly under the control or supervision of the State highway departments. The remaining 8 per cent not applied to road work was expended very largely for number



plates and in carrying out the provisions of the motor-vehicle registration laws of the several States.

The approximate relations and rates of variation of the three factors, total rural road and bridge expenditures, motor-vehicle registration and license revenues, and number of motor-car registrations from 1903 to 1919, inclusive, are shown graphically on the accompanying chart.

On January 1, 1920, every State but Minnesota had made provision for some definite form of annual State registration. In Minnesota the registrations are for a period of three years, beginning January 1, 1918. Consequently, only new cars will be registered and pay a fee during 1920; the registrations made during 1918 and 1919, respectively, being effective until the close of the calendar year 1920.

USE OF MOTOR TAX FOR ROAD WORK.

For a number of years a general tendency toward devoting an ever-increasing portion of the net motor-vehicle revenues to road work under the control and direct supervision of the State highway departments has been very noticeable. Prior to 1912 only a very small portion of the motor-vehicle revenues were devoted to road work under the State highway departments, while in 1919, 66 per cent of the total motor-vehicle revenues, or $42,492,604.17, were applied to road work under the direct supervision of the State

TABLE I.—Motor Vehicle Registrations and Revenues, 1919.

State.	Automobiles.	Motor trucks and commercial vehicles.	Motorcycles.	Reregistrations or transfers.	Owners' and chauffeurs' licenses.	Manufacturers' and dealers' licenses.	Total gross motor-vehicle registration and license revenues.	Motor-vehicle revenues available for road work.		Average gross revenue return per motor car registration.	Population per motor car.	Motor cars per mile of public rural road.
								By or under State highway department.	Under direction of local authorities.			
Alabama	48,649	10,249	1,103	[1]	1,521		$541,348.70			$9.19	41	1.1
Arizona	28,979	[1]	596	1,697	484	250	164,755.68	$164,755.68		5.68	10	2.4
Arkansas	49,450	[1]		284	1,008	532	500,970.00	425,970.00		10.13	36	1.0
California	[2] 477,450	[1]	28,028	64,828	726,219	3,218	4,468,721.67	1,913,651.66	$1,913,651.66	9.36	7	7.8
Colorado	104,865	[1]	3,636	7,212	10,291	2,456	490,432.31	215,642.82	215,642.82	4.68	10	2.7
Connecticut	83,549	18,861	4,495		117,350	582	1,516,136.91	1,516,136.91		14.80	13	7.3
Delaware	16,152	[1]	699		19,725	412	286,333.00	286,333.00		17.73	13	4.4
District of Columbia	[3] 29,800	[4] 5,600	2,412		19,096	946	274,184.00			7.74	11	
Florida	48,594	6,806	1,412	1,249	2,007	430	401,317.40	[5] 294,100.00		7.24	17	3.1
Georgia	127,000	10,000	1,722	22,940	4,125	1,070	429,848.00		304,134.78	3.14	22	1.7
Idaho	42,220	[1]	731	620	906	512	729,702.94	182,425.73	547,277.21	17.28	11	1.7
Illinois	478,438	[1]	10,920	20,548	53,123	4,960	3,262,714.00	3,262,714.00		6.82	13	5.0
Indiana	227,255	[1]	8,995		6,410	1,192	1,558,740.50		1,468,281.76	6.86	13	3.1
Iowa	364,043	[1]	3,035			3,000	3,077,445.81	153,872.29	2,769,701.23	8.42	6	3.5
Kansas [9]	228,600	[1]	4,000			1,500	1,150,000.00		1,000,000.00	5.00	8	2.1
Kentucky	80,903	9,105	1,503		5,000	743	565,520.21	565,520.21		6.26	27	1.6
Louisiana	45,900	5,100	500				306,000.00		275,400.00	6.00	37	2.1
Maine	47,630	5,795	1,608	4,023	66,188	476	685,570.25	685,570.25		12.83	15	2.3
Maryland	84,828	[6] 10,806	5,872	5,583	45,764	3,360	1,776,410.22	1,277,580.31	319,395.08	18.47	15	5.8
Massachusetts	205,372	41,810	13,698	27,979	297,962	2,496	2,667,853.85	[7] 2,329,522.26		10.79	16	13.2
Michigan	288,708	37,105	7,875	28,906	448,315	967	3,719,433.39	1,694,046.76	1,694,046.76	11.41	10	4.4
Minnesota [8]	259,741	[1]	6,389	3,073	7,039	241	218,469.50	218,469.50		.84	9	2.8
Mississippi [9]	56,009	3,000	1,200				400,000.00		400,000.00	6.78	34	1.3
Missouri	244,363	[1]	4,131	14,850	23,871	2,059	1,725,076.70	1,585,155.72		7.06	14	2.5
Montana	59,321	[1]	847		1,750	429	407,848.00	368,127.33	92,031.83	6.88	9	1.5
Nebraska	185,000	15,000	2,500	700		2,700	304,450.55	228,337.92	76,112.63	1.52	7	2.5
Nevada	9,305	[1]	125			65	37,550.75	30,744.75	2,040.50	4.04	13	.8
New Hampshire	27,882	3,743	2,632	4,069	39,675	227	599,621.25	538,621.25		18.96	14	2.2
New Jersey	171,374	19,499	11,416	39,173	251,539	1,725	2,931,902.15	2,880,033.13		15.36	17	12.9
New Mexico	18,082	[1]	200			100	111,150.00	100,000.00		6.14	25	.4
New York	446,593	119,918	28,561		181,632	2,681	5,984,659.50	3,132,628.97	2,852,030.53	10.56	19	7.1
North Carolina	99,825	9,192	1,159			979	1,313,950.73	1,051,160.58		12.05	23	2.1
North Dakota	81,571	1,314	901				636,842.40	318,421.20	318,421.20	7.68	10	1.3
Ohio	511,031	[1]	20,000	13,500		4,000	2,593,000.00	2,411,490.00		5.07	10	5.9
Oklahoma	144,500	[1] [10]	1,310			1,286	1,178,130.27	1,058,859.19		8.15	17	1.3
Oregon	83,332	[1]	3,570	14,124	3,152	586	602,239.00	544,073.64		7.23	11	2.2
Pennsylvania	441,224	[11] 40,893	25,760	56,477	88,704	10,719	5,090,921.00	5,090,645.69		10.56	19	5.3
Rhode Island	36,494	8,339	2,301	5,264	49,279	246	477,223.25	428,866.77		10.64	15	20.6
South Carolina	61,143	9,000	869	1,994		1,293	389,034.68	77,806.94	311,227.74	5.55	24	1.6
South Dakota	104,628	[1]	880	1,213		1,218	322,340.50		273,989.43	3.08	7	1.1
Tennessee	80,422	[1]	1,133	5,720		456	585,181.95	62,357.10	395,712.32	7.27	29	1.7
Texas	331,310	[1]	3,889	69,911	25,618	3,272	2,624,334.29	1,053,177.59	1,294,152.53	7.92	14	2.6
Utah	30,236	5,000	1,185		1,122	203	291,325.96	275,000.00		8.27	13	4.0
Vermont	24,405	2,402	800	2,878	33,597	180	460,190.87	344,023.39	75,000.00	17.17	14	1.9
Virginia	94,100	[1]	2,520	3,000	2,600	546	900,000.00	850,000.00		9.56	24	1.8
Washington	136,500	12,275	5,050	10,838		439	2,325,323.53	2,215,323.53		15.12	12	3.5
West Virginia [12]	50,203	[1]	994	3,473	5,544	664	1,008,083.31	850,000.00	130,776.40	20.08	29	1.6
Wisconsin	225,410	10,880	7,223			1,396	2,502,852.00	1,811,438.00	603,814.00	10.59	11	3.1
Wyoming	[1] 21,371	[1]	353			194	102,114.50		81,691.60	4.78	9	1.5
Total and average	7,143,954	[13] 421,692	241,038	[13] 436,126	2,540,606	67,006	64,697,255.58	42,492,604.17	17,411,532.01	8.54	14.0	3.05

[1] Included under automobiles.
[2] Does not include 1,647 trailers, and 10,000 cars operated under exempt license.
[3] Does not include 18,300 nonresident registrations.
[4] Does not include about 2,000 nonresident registrations.
[5] Does not include 51,900 for maintenance of State Highway Department.
[6] Does not include 312 traction engines registrations.
[7] 80 per cent to State roads and 20 per cent for town roads.
[8] Registration for a 3-year period. Includes all vehicles registered first 2 years.
[9] Approximate.
[10] Does not include 2,781 traction engines registrations.
[11] Does not include 3,531 traction engines registrations.
[12] This registration period covers 18 months, July 1, 1918, to January 1, 1920.
[13] Partial total.

highway departments. The remainder, or $17,414,532.01, was expended for road work by counties or other local subdivisions with little or no direct supervision from the State highway departments.

In most States the motor-vehicle revenues are devoted to the maintenance and repair of the State roads or other improved highways. These States thus seem to have solved fairly well the difficult problem of securing funds for the maintenance of the more important roads under the ever-increasing traffic requirements. As both the traffic and the revenues increase with the number of cars, there exists a possibility of so adjusting the registration rates as to keep pace with the ever-growing maintenance changes.

A number of States having but a small mileage of improved roads have recently adopted the plan of capitalizing the motor-vehicle revenues and devoting these funds to road construction. These States are Alabama, Illinois, Maine, Minnesota, Nevada, and Utah. In these States bonds have been issued for road construction, the interest and principle of which are to be paid entirely from the motor-vehicle revenues. There seems to be no doubt that these revenues will prove sufficient for this purpose. The question which remains to be solved in these States is, what other source will yield sufficient maintenance revenues to prevent the deterioration of the roads constructed from these bond issues.

The total road mileage in the United States, outside of incorporated towns and cities, is about 2,475,000 miles. With a total registration of 7,565,446 motor cars, there was, therefore, an average of 3 motor cars for every mile of public roads in the United States. The distribution of cars in the United States, however, is

TABLE II.—Motor-car Registrations and Gross Motor-Vehicle Revenues, 1914 to 1919.

	Motor-car registration.[1]						Total gross revenues.					
	1914	1915	1916	1917	1918	1919	1914	1915	1916	1917	1918	1919
Alabama	8,672	11,634	21,636	32,873	46,171	58,898	$113,202	$180,744	$203,655	$217,700	$470,274	$541,348.70
Arizona	5,040	7,753	12,300	19,800	23,905	28,979	34,077	45,579	73,000	117,643	142,288	164,755.68
Arkansas	5,642	8,021	15,000	28,693	41,458	49,450	56,420	80,551	150,000	205,176	410,649	500,970.00
California	123,504	163,797	232,440	306,916	407,761	477,450	1,338,785	2,027,432	2,192,699	2,846,030	3,524,036	4,468,721.67
Colorado	17,756	28,894	43,296	87,460	83,244	104,865	80,047	120,801	197,795	296,808	379,559	490,432.31
Connecticut	27,786	41,121	56,048	74,645	86,067	102,410	406,623	536,970	768,728	1,080,757	1,285,164	1,516,136.91
Delaware	3,050	5,052	7,102	10,700	12,955	16,152	35,672	55,596	85,249	133,883	232,449	286,333.00
District of Columbia	4,833	8,009	13,118	15,493	30,490	35,400	20,147	29,396	47,624	55,928	220,753	274,184.00
Florida	[2] 3,368	[2] 10,850	20,718	[3] 27,000	54,186	55,400	[4] 6,736	[3] 60,000	127,176	[3] 170,000	345,775	401,317.40
Georgia	20,915	25,000	46,025	70,324	104,676	137,000	104,575	125,000	154,735	229,653	331,816	429,848.00
Idaho	3,346	7,071	12,999	24,731	32,289	42,220	58,580	121,259	213,758	412,641	576,555	729,702.94
Illinois	131,140	180,832	248,429	340,292	389,620	478,438	699,725	924,906	1,236,566	1,588,835	2,764,330	3,262,714.00
Indiana	66,500	96,915	139,065	192,194	227,160	227,255	432,309	587,348	817,285	1,096,159	1,293,128	1,558,740.50
Iowa	106,087	145,109	198,587	254,462	278,313	364,043	1,040,136	1,533,054	1,776,170	2,249,655	2,547,596	3,077,445.81
Kansas	49,374	72,520	112,122	159,343	189,163	228,600	268,471	387,588	585,762	830,878	978,837	1,150,000.00
Kentucky	11,766	19,500	31,500	47,420	65,884	90,008	85,883	117,117	184,741	287,314	402,250	565,520.21
Louisiana	[3] 12,000	11,380	17,000	28,394	40,000	51,000	[3] 12,000	75,600	112,000	166,835	240,000	306,000.00
Maine	15,700	21,545	30,972	41,499	44,572	53,425	192,542	268,442	363,562	491,696	570,171	685,570.25
Maryland	20,213	31,047	44,245	60,943	74,666	95,634	268,231	386,565	565,302	807,395	1,189,984	1,776,410.22
Massachusetts	77,246	102,633	136,809	174,274	193,497	247,182	923,961	1,235,724	1,602,958	1,969,994	2,184,821	2,667,853.85
Michigan	76,389	114,845	160,052	247,006	262,125	325,813	(4)	373,833	1,739,344	2,471,271	2,875,266	3,719,433.39
Minnesota	67,862	93,269	[5] 46,000	[6] 54,009	204,458	259,741	132,398	[3] 160,540	82,469	100,000	1,076,811	218,469.50
Mississippi [3]	5,694	9,669	25,000	36,600	48,400	59,000	51,146	76,700	175,000	250,000	335,000	400,000.00
Missouri	54,468	76,462	103,587	147,528	188,040	244,363	235,873	323,289	439,315	617,942	1,394,762	1,725,076.70
Montana	10,200	14,540	25,105	42,749	51,053	59,324	27,000	33,120	52,768	290,936	350,914	407,848.00
Nebraska	16,385	59,000	101,200	148,101	173,374	200,000	34,325	[3] 183,000	311,334	451,303	536,897	304,450.55
Nevada	1,487	2,009	4,919	7,160	8,159	9,305	4,331	7,875	20,116	31,166	31,083	37,550.75
New Hampshire	9,571	13,449	17,508	22,267	24,817	31,625	185,288	257,776	344,434	425,305	509,335	599,621.25
New Jersey	62,961	81,848	109,414	141,918	155,519	190,873	814,536	1,062,923	1,405,806	1,923,164	2,431,757	2,931,904.15
New Mexico	3,090	5,100	8,228	14,086	17,647	18,082	19,663	29,625	47,865	80,843	105,631	111,150.00
New York	168,223	255,242	314,222	406,016	459,292	566,511	1,523,852	1,991,181	2,658,042	4,284,144	4,945,298	5,984,659.50
North Carolina	14,677	21,000	33,904	55,950	72,313	109,017	89,580	123,000	206,101	321,923	394,739	1,313,950.73
North Dakota	17,347	24,908	40,446	62,993	71,678	82,885	55,964	79,245	125,283	211,536	471,429	636,842.40
Ohio	122,504	181,332	252,431	346,772	412,775	511,031	685,457	984,622	1,286,405	1,766,427	2,125,426	2,593,000.00
Oklahoma	13,500	25,032	52,718	100,199	121,500	144,500	13,500	154,892	555,011	853,659	1,102,380	1,178,130.27
Oregon	16,447	23,585	33,917	48,632	63,324	83,332	77,592	108,881	146,232	196,787	461,422	602,239.00
Pennsylvania	112,854	160,137	230,578	325,153	394,186	482,117	1,185,039	1,665,276	2,325,057	3,268,025	4,048,186	5,090,921.00
Rhode Island	12,331	16,362	21,406	37,046	35,218	44,833	157,020	205,440	264,737	346,117	385,608	477,223.25
South Carolina [2]	14,000	15,000	[7] 25,000	38,332	55,492	70,143	14,000	15,000	10,000	113,557	300,217	389,034.68
South Dakota	20,929	28,724	44,271	67,158	90,521	104,628	125,000	[3] 180,000	140,746	210,592	282,742	322,340.50
Tennessee	[8] 19,769	[9] 7,618	[3] 30,000	48,000	63,000	80,422	39,538	[3] 34,000	186,953	322,200	390,000	585,181.95
Texas [2]	40,000	40,000	[7] 125,000	192,961	251,118	331,310	20,000	20,000	20,000	858,978	2,039,589	2,624,334.29
Utah	2,253	9,177	13,507	24,076	32,273	35,236	4,852	[3] 60,000	93,494	170,707	229,203	291,325.96
Vermont	8,475	11,499	15,671	21,633	22,553	26,807	154,267	218,480	297,992	363,541	398,856	460,190.87
Virginia	13,984	21,357	35,426	55,661	72,228	94,100	120,814	176,875	271,266	518,566	684,636	900,000.00
Washington	30,253	38,823	60,734	91,337	117,278	148,775	60,506	238,717	350,052	519,526	875,391	2,325,323.53
West Virginia	6,159	13,279	20,571	31,300	38,750	59,203	60,648	128,952	198,436	359,339	447,705	1,008,083.31
Wisconsin	53,161	79,741	115,645	158,637	196,253	236,290	293,580	431,977	615,721	861,278	2,076,701	2,502,852.00
Wyoming	2,428	3,976	7,125	12,523	16,200	21,371	12,140	19,880	35,625	57,421	80,000	102,114.50
Total	1,711,339	2,445,664	3,512,996	4,983,340	6,146,617	7,565,446	12,381,951	18,245,711	25,865,370	37,501,233	51,477,417	64,697,255.58

[1] Does not include motor cycles nor dealers' and manufacturers' licenses.
[2] State registrations only.
[3] Estimated.
[4] Registration law declared unconstitutional.
[5] Cars registered during 1916; total number of cars, approximately 138,000.
[6] Cars registered, 1917.
[7] Estimated number of cars in State.
[8] Total cars registered under perennial system.
[9] Registrations 1915 only.

far from uniform. Thus, New Mexico and Nevada have less than 1 car per mile of road, while Rhode Island has 21 cars, Massachusetts and New Jersey 13, and California 8 cars per mile. Furthermore, while there was an average of 1 motor car for every 14 people in the United States, in the State of Iowa there was 1 motor car for every 6 persons, in California, Nebraska, and South Dakota, 1 for every 7, and 1 for every 8 in Kansas, but only 1 car for every 41 persons in Alabama, 37 in Louisiana, 36 in Arkansas and 29 in Tennessee and West Virginia.

INCREASED FEES ON HEAVY TRUCKS.

At the beginning of 1920 there were still 12 States in which motor trucks were registered at the same rate as passenger cars. The past four or five years, however, have shown a very decided tendency toward increasing the fees required for heavy motor trucks over and above those required for passenger cars. This increase is usually based on the weight of the truck, its carrying capacity, its horsepower, or a combination of these factors. The most general practice seems to be toward definitely limiting the maximum total weight of the loaded vehicle and basing the registration fee on the carrying capacity of the truck. A few States specify no maximum load limit but provide a rapidly increasing rate per ton of load so as to discourage effectively the use of extremely heavy trucks. A number of States have also provided legislation to limit the maximum wheel load per inch of tire. It is unfortunate that the term motor truck and commercial vehicle is as yet rather indefinitely defined in the laws of a number of the States. In a few States no distinction is made between passenger and freight carrying cars, while in one State only trucks used for hire are classed as commercial vehicles.

The amount of fees collected per car for either pleasure or commercial vehicles is as yet far from uniform, and is still further complicated by the widely varying requirements for the registration or licensing of chauffeurs, owners, operators, dealers, etc. Thus, if the total gross registration and license revenues be used as a basis of revenues, and the total automobiles, trucks, and commercial vehicles as the basis for motor cars, it is found that for the entire United States the average fee per car for 1919 was $8.54. On the same basis the State of West Virginia received $20.08 per car, New Hampshire, $18.96, Maryland, $18.47, and Vermont, $17.17; while the State of Minnesota received only an average of 84 cents for each car registered within its borders, as in that State the registration is for a three-year period, the first year of which was 1918.

The States of Colorado, New Mexico, and Oregon devised an additional method of securing road revenues by levying a State tax on gasoline or other products used for the propulsion of motor vehicles. In Alabama, Delaware, Idaho, Iowa, Michigan, New York, North Dakota, Oklahoma, South Carolina, Pennsylvania, and Vermont the registration fees are in lieu of all other taxes. In other States, however, motor cars are taxed as personal property in addition to the required registration fees. Therefore, in making any comparison of fees as between the several States, this fact should be borne in mind.

TABLES FURNISH INDEX.

The registration of automobiles, motor trucks, commercial vehicles, chauffeurs and operators, dealers, and manufacturers, as well as the total gross revenues and the amount available for State road work, either by the State highway departments or under their supervision, for the year 1919, are given in Table I. The number of registrations in this table does not necessarily indicate the exact number of motor vehicles in actual use or existence in the United States, except in so far as the laws of the several States require and enforce an annual registration under these classifications. However, as all the States, with the exception of Minnesota, now require an annual State registration, these figures should furnish a very reliable index of the total number of cars in each of the several States. It is unfortunate that, during 1919, only 25 States required motor trucks and commercial vehicles to be registered in separate classes. Consequently the data in column 3 of Table I does not give a very definite index as to the total number of trucks in existence, except in those States requiring separate registration. Reference to the principal requirements for the registration of motor vehicles as given in Table IV will serve to make clear what the data in Table I actually represent.

Table II gives a compilation of the total registrations and total revenues for the years 1914 to 1919, inclusive. For further information in regard to registrations and revenues previous to 1913, the reader is referred to the graphic chart, and to Office of Public Roads Bulletin No. 48, "Repair and maintenance of highways," pages 68 to 71.

TABLE III.—Motor-vehicle registration and license fees in force January 1, 1920.

State.	Motorcycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
Alabama	$3; with side-car attachment, $5.	Less than 25 horsepower, $7.50; 25 to 29 horsepower, $12.50; 30 to 39 horsepower, $17.50; 40 horsepower and over, $20; electric cars, $12.50; steam cars, $15.	Same as passenger cars, except that those over 40 horsepower pay $25 each.[1]	Original, $5; renewal, $2.50.	None	$25 to $125.

[1] Cars used for transportation of passengers paying fare, 5 or less passenger capacity, $25; 6 to 9 passenger capacity, $40; 10 or more passenger capacity, $60; operating between towns or cities 10 miles or more apart, a flat fee of $40.

TABLE III.—Motor-vehicle registration and license fees in force January 1, 1920.—Continued.

State.	Motorcycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
Arizona	$2	25 horsepower and under, $5; 26 to 40 horsepower, $10; over 40 horsepower, $15.	Same as passenger cars	Perpetual, $5.	None	1 vehicle of each class at pleasure-car rates.
Arkansas	None	All motor vehicles, $10	do	$1	do	Do.
California	$2	Electric cars, $5; all others, 40 cents per horsepower; trailers, $2.	Equipped with pneumatic tires, same as passenger cars; others pay additional; less than 2 tons unloaded, $5; 2 to 3 tons, $10; 3 to 5 tons, $15; over 5 tons, $20.	Original, $2; renewal, $1.	No fee	Regular rates for each set of plates.
Colorado	Same rate as passenger cars.	One-half of 1 per cent of cost price; minimum fee, $5.	1 ton, $10; 2 tons, $17.50; 3 tons, $25; 4 tons, $37.50; 5 tons, $50, and $25 per ton for each additional ton, carrying capacity.	$2	None	$20; additional tags, $2.50 per set.
Connecticut	$2	50 cents per horsepower	½ ton or less, $11; 1 ton, $15, and increasing to $200 for 8 tons, and $100 per ton for each ton additional.	License, $2; examination, $2.	License, $2; examination, $2.	$50 for 5 pair of plates, additional plates, $10 per pair.[1]
Delaware	$5	$2 each 500 pounds gross weight of car and load; passengers figured at 125 pounds each.	Same as passenger cars	$3	$3; family, $8.	$20 for 2 pairs of tags; extra tags, $10 per pair.
District of Columbia.	$2	24 horsepower or less, $3; 25 to 30 horsepower, $5; over 30 horsepower, $10.	do	$2	$2	Regular rates for each car demonstrated on public roads.
Florida [2]	$2	22 horsepower or less, $5; 23 to 27 horsepower, $8; 28 to 35 horsepower, $12; above 35 horsepower, $15; any car seating more than 9 persons, $100.	1 ton or less, $10; 1 to 2 tons, $25; 2 to 4 tons, $50; more than 4 tons, $100. Trailers over 500 pounds capacity same rate as trucks.	$2	None	5 cars, $15.
Georgia	$5	Not exceeding 23 horsepower, $11.25; over 23 horsepower 60 cents per horsepower.	Not exceeding 1 ton capacity, $15; others, $15 plus $7.50 for each ½ ton over 1 ton; 4 tons, $75; 5 tons, $150; 6 tons, $375; 7 tons, $1,125.	$2	do	$50 for 5 number plates.
Idaho	$5	All weighing less than 2,001 pounds, $15; 2,001 to 3,000 pounds, $20; 3,001 to 4,000 pounds, $30; over 4,000 pounds, $40.	Same as passenger cars	$2	do	$35 for one make and $25 each additional make.
Illinois [3]	$1	25 horsepower or less, $8; 26 to 35 horsepower, $12; 36 to 50 horsepower, $20; over 50 horsepower, $25; electric cars, $12.	Total loaded weight, 5,000 pounds or less, $12; 5,000 to 12,000 pounds, $22.50; 12,000 to 15,000 pounds, $35; over 15,000 pounds, $60.	Original, $5; renewal, $3.	do	$12 for 2 plates and $12 for each pair duplicates.
Indiana	$2	Electric cars, $5; others, 25 horsepower or less, $5; 26 to 40 horsepower, $8; 41 to 50 horsepower, $15; over 50 horsepower, $20.	Less than ¾ ton, $6; 1 ton, $8; 1 to 2 tons, $10; 2 to 3½ tons, $20; 3½ to 5 tons, $30; 5 to 7½ tons, $40; over 7½ tons, $50.	$2	do	$25; duplicate plates, $1 each.
Iowa	$5	One per cent of values of car plus 40 cents per 100 pounds of weight of vehicle. Minimum fee, $10.	With pneumatic tires—1 ton capacity or less, $15; 1½ tons, $22.50; 2 tons, $30; 2½ tons, $45; 3 tons, $65; 3½ tons, $90; 4 tons, $105; 4½ tons, $120; 5 tons, $135; 6 tons, $165. With solid rubber tires—less than 2-ton capacity, same as above, 2½ tons, $55; 3 tons, $75; 3½ tons, $100; 4 tons, $115; 4½ tons, $130; 5 tons $145; 6 tons, $175; trailers, $10 to $70.	$2	do	$25.
Kansas	$2	All cars, $5 each	Same as passenger cars	None	do	$15 for 3 sets of tags; extra tags, 50 cents each.
Kentucky	$5	Less than 25 horsepower, $6; 25 to 50 horsepower, $11; 50 horsepower and over, $20.	½ ton or less, $11; 1 ton, $15; and increasing to $75 for 5 tons, and $50 per ton for each ton additional.	Original, $2; renewal, $1.	do	1 registration for each class at regular rates.
Louisiana	$2	25 cents per horsepower, with a minimum fee of $5 per car.	All motor trucks, $7.50 each.	None	do	1 regular registration for each make; second-hand dealers, $10.
Maine	$3	15 horsepower or less, $5; 16 to 35 horsepower, $10; over 35 horsepower, $15.	$10 per ton capacity for cars to 5-ton capacity, then $15 per ton for each ton above 5-ton capacity.	$2	$2	$25 for 5 pairs of plates; extra plates, 75 cents each.
Maryland	$5; with side car, $8.	60 cents per horsepower; minimum charge, $10; $1.20 per horsepower if operated for hire.	With solid tires to 3-ton capacity, $20 per ton; 4-ton, $100; 5-ton, $150; 6-ton, $300; 7-ton, $500; electries, one-half of above rates; trailers to 1-ton capacity, $10; others, $20 per ton.	$3	$2	$25 for 2 sets of tags and $12 for each additional set. For dealers in motorcycles, 4 tags, $20; additional tags, $5 each.
Massachusetts	$2	Under 20 horsepower, $5; 20 to 29 horsepower, $10; 30 to 39 horsepower, $15; 40 to 49 horsepower, $20; 50 horsepower and over, $25.	$10 for each ton capacity or fraction thereof.	Original, $2; renewal, $1; examination, $2.	Original, $2; renewal, $1.	$10, motor cycles; $25, motor vehicles, and $5 additional for each car over 5 operated on public roads.
Michigan	(4)	Electric cars, $1 for each motor horsepower plus 35 cents for each 100 pounds of weight; others, 25 cents per horsepower plus 35 cents for each 100 pounds of weight.	Same rates as passenger cars. Trailers, 50 cents for each 100 pounds of weight.	$2	$0.50	$30 for 3 cars and $10 for each additional car.[5]
Minnesota	$2	All cars, $2 for year 1920	Same as passenger cars	Original, $1.50; renewal, $1.	None	$20; extra plates, $1 per set.
Mississippi	State, $2; county, $2.	State, $2; county, electric cars, $4.80; others, 24 cents per horsepower.	4,100 pounds capacity or less, $6.40; over 4,400 pounds, $12.80.	None	do	Regular rates for 4 sets of plates.

[1] In case of manufacturers, $25, plus $1 for each car tested on public roads.
[2] Any county or municipality may charge an additional license tax, not to exceed 50 per cent of State license tax, on motor vehicles used for hire.
[3] Both cars and trucks may be registered in municipality in which owner resides.
[4] Same rate as passenger cars.
[5] In case of manufacturers, motorcycles $20, including 10 number plates.

TABLE III.—Motor-vehicle registration and license fees in force January 1, 1920—Continued.

State.	Motorcycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
Missouri	(a)	Less than 12 horsepower, $4; 12 to 23 horsepower, $6; 24 to 35 horsepower, $10; 36 to 47 horsepower, $14; 48 to 59 horsepower, $16; 60 to 71 horsepower, $20; 72 horsepower and over, $24.	Same as passenger cars	$1.50	None	$10; for each duplicate, $5.
Montana	$5	23 horsepower or less, $5; 24 to 50 horsepower, $10; over 50 horsepower, $15.	One-ton capacity or less, $5; over 1 ton and less than 2, $15; over 2 tons and less than 3, $25; over 3 tons, $40.	$2	do	Cars, $50; motor cycles, $15.
Nebraska	$5	$10, plus 50 cents for each 100 pounds car weighs over 2,000 pounds.	$10, plus 50 cents for each 100 pounds total weight of loaded car exceeds 2,000 pounds.	None	do	Registration for each class.
Nevada	(b)	35 cents for each 100 pounds of total weight of loaded car.	Same as passenger cars.	do	do	$20 for 4 number plates; $1 for each duplicate.
New Hampshire	$2	15 horsepower or less, $10; 16 to 30 horsepower, $15; 31 to 40 horsepower, $20; 41 to 50 horsepower, $25; 51 to 60 horsepower, $30; over 60 horsepower, $40.	do	Original, $5; renewal, $1.	Original, $3; renewal, $1.	Cars, $50; motor cycles, $5.
New Jersey	$2	10 horsepower or less, $4.50; 11 to 29 horsepower, $7.50; 30 horsepower or over, $15.	With solid tires loaded weight ½ ton or less, $6, and $3 additional for each one-half ton gross weight to 2 tons; then $4 for each additional ton; trailers, $3.	$3	$3	$5 per car not to exceed 5.
New Mexico	$3	40 cents per horsepower	50 cents per horsepower	None	None	$25, additional tags $5 each.
New York	$2.50	25 cents per horsepower plus 40 cents per $100 of list price.	Gross loaded weight 2 tons or less, $10, and $5 each additional ton to 14; 14 tons, $70, and $10 each additional ton.	Original, $5; renewal, $2.	Original, $2; renewal, $1.	$15, plus $5 for each duplicate set.
North Carolina	$5	26 horsepower or less, $10; 26 to 30 horsepower, $15; over 30 horsepower, $20.	One ton capacity or less, $12.50; 1 to 2 tons, $25; 2 to 3 tons, $40; 3 to 4 tons, $65; 4 to 5½ tons, $100. Trailers, 1 ton capacity, $10, plus $20 for each additional ton.	None	None	$25, plus $5 for each duplicate pair of plates.
North Dakota	$3	10 cents per horsepower, plus 5 mills per dollar of selling price and 20 cents per 100 pounds net weight of car. Minimum fee, $5. Electric cars, $2.	Same as passenger cars, plus following fee for capacity rating: To 3 tons, $3 per ton; to 4 tons, $5 per ton; over 4 tons, $10 per ton. Trailers, ½ truck fee.	do	do	Dealer pays regular fee and transfers tags to purchaser.
Ohio	$2.50	25 horsepower or less, $8; 25 to 35 horsepower, $12; over 35 horsepower, $20.	Same as passenger cars, plus 20 cents for each 100 pounds of total loaded weight.	$3	do	Regular rates for each class. Extra plates, $2 per pair.
Oklahoma	(b)	50 cents per horsepower first year; second, 40 cents per horsepower; third, 30 cents per horsepower; and thereafter 20 cents per horsepower.	Same as passenger cars	None	do	$15 for 2 tags and $1 each for additional tags.
Oregon	$6	Electric cars, $18; others, 23 horsepower and less, $15; 23 to 26 horsepower, $22; 26 to 30 horsepower, $28; 30 to 36 horsepower, $36; 36 to 40 horsepower, $48; over 40 horsepower, $56.	Electric trucks, $30; others, 1½ to 2 tons, $32, and $12 for each additional one-half ton up to 5 tons; over 5 tons allowed only on special permits.	$4	do	$30 for 2 tags and $5 for duplicate sets.
Pennsylvania	$3	40 cents per horsepower	Less than 1 ton weight same as passenger cars; others, 1 to 1½ tons, $20; 1½ to 2¼ tons, $25; 2¼ to 3 tons, $30; 3 to 3¼ tons, $50; 3½ to 4 tons, $75; 4 to 5 tons, $100; over 5 tons, $150. With metal tires double above rates. Trailers, $2 to $15.	$2	No fee	$10.
Rhode Island	$2	15 horsepower or less, $5; 16 to 30 horsepower, $10; 31 to 40 horsepower, $15; over 40 horsepower, $25.	Carrying capacity 1 ton or less, $7, with $3 additional for each ton to 4 tons, and then $4 for each ton above 4 tons; over 9-ton capacity, $40 each; trailers, $10 to $30 each.	$1	$1	$25 for 5 vehicles and $5 for each additional vehicle.
South Carolina	(b)	25 cents per horsepower	Same as pleasure cars	None	None	$15 for each make.
South Dakota	$3	All cars $6 each	Capacity 2 ton or less, $6; 2 to 3½ tons, $10; 3½ to 5 tons, $15.	do	do	$25 for 6 plates, duplicates $3 each.
Tennessee	(b)	50 cents per horsepower	50 cents per horsepower, plus $5 per ton carrying capacity.	do	do	$25.
Texas	$3	35 cents per horsepower	Capacity 1 ton or less, same as passenger cars; others, 1 to 2 tons, $16; 2 to 3 tons, $32; 3 to 4 tons, $48; 4 to 5 tons, $80; above 5 tons, $100 for additional ½ ton. County license also required.	$3	do	$15; extra numbers, $5 each.
Utah	$3	Electric cars, $10; others, 25 horsepower and less, $5; 26 to 40 horsepower, $10; above 40 horsepower, $15.	Total loaded weight 1 ton or less, $10; 1 to 2 tons, $15; over 2 tons, $7.50 per ton. With pneumatic tires two-thirds and with metal tires double above rates.	$2	do	$25, and $2 for each set of duplicate plates.
Vermont	(b)	First registration, $1 per horsepower; second, 75 cents per horsepower; third registration and thereafter, 50 cents per horsepower.	Less than 3-ton capacity, $20 per ton; 3 tons and over, $25 per ton.	$3; examination, $2.	$2	$50.
Virginia	60 cents per horsepower; minimum, $5.	60 cents per horsepower; minimum fee, $10.	$15 for first ton capacity, plus $5 for each ½ ton additional capacity. Trailers, $10 first ton capacity, plus $3 for each ½ ton additional.	$5	None	$50 for 3 sets of plates; additional sets, $15 each.

[a] Same rate as passenger cars.

TABLE III.—Motor-vehicle registration and license fees in force January 1, 1920—Continued.

State.	Motorcycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
Washington	$6	$10, plus 60 cents for each 100 pounds car weighs over 1,500 pounds.	$10, plus 40 cents for each 100 pounds that total loaded weight exceeds 1,500 pounds, unless empty truck weight exceeds 6,500 pounds, then 50 cents per 100 pounds. Trailers same rates.	None	None	Cars, $50; extra plates, $10 per pair; motor cycles, $10.
West Virginia	$5	Cars weighing 1 ton or less, $10, and 25 cents additional for each 100 pounds over 1 ton.	Same as passenger cars. Special rates for trucks used for hire.	$3	do	Cars, $15 per set of plates; motor cycles, $5.
Wisconsin	$4	All cars $10 each	Capacity less than 2,100 pounds, $15; 2,100 to 5,100 pounds, $20; 5,100 pounds or more, $25.	(7)	do	$25 for 4 plates; extra plates, $1 each.
Wyoming	$5	40 cents per horsepower	75 cents for each 100 pounds of weight of vehicle.	None	do	$50 for 1 plate; $2 for each additional plate.

[7] Drivers of cars operating for hire may be licensed by municipality.

TABLE IV.—Administrative provisions in force January 1, 1920, affecting motor-vehicle registrations, licenses, and revenues.

State.	Registration and licenses.					Revenues from registrations and licenses.			Revenues from fines and penalties applied to roads.	Traffic regulations made by—
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Nonresidents' exemption.	Applied to—	Proportion expended for roads under supervision of—			
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
Alabama	State board of equalization through probate judge.	Annual, Oct. 1.	Chauffeur, annual, Oct. 1.	Chauffeur, must be 18 years old.	Reciprocity.	State highway fund.	All of net[1].	None	None	Statute.
Arizona	Secretary of State	Annual, Jan. 1.	Chauffeur, perpetual.	No examination.	6 months	State road tax fund.	All of net.	do	do	Statute and local ordinance.
Arkansas	Commissioner of State lands, highways and improvements.	do	Chauffeur, annual from date.	Chauffeur must be 18 years old.	Reciprocity.	State and county road fund.	One-half	One-half	One-half of penalty for delinquency.	Do.
California	Superintendent of motor-vehicle department.	do	Chauffeur, annual, Jan. 1.	do	3 months	State and county road work.	One-half net.	One-half net.	All, by local community.	Do.
Colorado	Secretary of State	do	Chauffeur, annual, Jan. 1.	Certificate as to competency.	90 days	do	do	do	Same as registration revenues.	Do.
Connecticut	Commissioner of motor vehicles.	do	All operators, Mar. 1.	Examination.	30 days	Maintenance State roads.	All of net.	None	do	Do.
Delaware	Secretary of State	do	All operators, Jan. 1.	Must be 16 years old; no examination.	Reciprocity.	State highway department.	All	do	None	Do.
District of Columbia.	Automobile board	do	All oporators, perpetual.	Examination	do	General fund	None	do	do	
Florida	State comptroller	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	do	State highway department and State, maintenance fund.	All of net.	do	do	Do.
Georgia	Secretary of State	Annual, Mar. 1.	Chauffeur, annual, Mar. 1.	Must be 16 years old.	30 days	Net to State aid road fund.	do	do	do	Do.
Idaho	State highway commission through county assessor.	Annual, Jan. 1.	Chauffeur, annual.	Chauffeur, must be 18 years of age.	Reciprocity.	State highway fund.	25 per cent	75 per cent	Same as registration revenues.	Do.
Illinois	Secretary of State	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	60 days	State road fund.	All[1]	None	All, by local community.	Do.
Indiana	do	do	do	do	do	State highway fund.	All of net.	do	County road fund.	Do.
Iowa	do	do	do	Chauffeur must be 18 years of age and competent.	Reciprocity.	State road work.	(2)	do	Local road work.	Do.
Kansas	Secretary of State through county treasurer.	Annual, July 1.	do	Must be 14 years of age.	60 days	Net, maintenance county and township roads.	None	All of net.	None	Statute and city ordinance.
Kentucky	State tax commission.	Annual, Jan. 1.	do	Chauffeur, examination.	Reciprocity.	Net to State road fund.	All of net.	None	do	Statute and local ordinance.
Louisiana	Secretary of State	do	None		do	Net to parish road work,	None	All of net.	Same as registration revenues.	Local ordinance.

[1] Must first set aside amount necessary to finance State highway bonds.
[2] 90 per cent for construction of primary roads, 5 per cent for maintenance of highway department, and 5 per cent for registration expenses.

TABLE IV.—Administrative provisions in force January 1, 1920, affecting motor-vehicle registrations, licenses, and revenues—Continued.

State.	Registration and licenses.					Revenues from registrations and licenses.				Traffic regulations made by—
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Nonresidents' exemption.	Applied to—	Proportion expended for roads under supervision of—		Revenues from fines and penalties applied to roads.	
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
Maine	Secretary of state	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination optional.	30 days	State road work.	All[1]	None	None	Statute and local ordinance.
Maryland	Commissioner of motor vehicles.	do	Owner, perpetual; chauffeur, annual.	do	Reciprocity; 3 months.	Net 20 per cent Baltimore street work; 80 per cent State road maintenance.	80 per cent of net.	do	Same as registration revenues.	Do.
Massachusetts	Department of public works.	do	All operators, annual from date.	Chauffeur, examination.	Reciprocity.	Net 20 per cent small town roads; 80 per cent maintenance State roads.	All net	do	do	Statute, department of public works and local ordinance.
Michigan	Secretary of state	do	Chauffeur, annual, Jan. 1.	Examination optional.	Reciprocity to 90 days.	State and county road work.	One-half net.	One-half net.	None	Statute and local ordinance.
Minnesota	do	Triennial. 1918–1920.	do	Chauffeur, examination.	30 days	Net, State road and bridge fund.	All net	None	do	Do.
Mississippi	State auditor and county tax collector.	Annual, Jan. 1.	None		60 days	State revenues to general fund; county to county road work.	None	Net county revenue.	Net, same as county revenue.	Local ordinance.
Missouri	Secretary of state	Annual, Feb. 1.	Chauffeur, annual, Feb. 1.	Must be 18 years of age; no examination.	do	State road fund.	All of net	None	None	Statutes and local ordinance.
Montana	do	Annual, Jan. 1.	Chauffeur, annual, Jan. 1.	No examination.	No limit	Net to State and county road work.	Three-fourths net.	One-fourth net.	do	Do.
Nebraska	Department of public works through county treasurer.	Annual, Jan. 1.	None	Must be 16 years old.	30 days	do	Three-fourths.	One-fourth	None	Statute and local ordinance.
Nevada	Secretary of state	First Monday in February	do	do	do	Net to State highway bond fund.	None	None	do	Do.
New Hampshire.	Commissioner of motor vehicles.	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination, all operators.	20 days	Road maintenance.	All of net	do	Same as registration revenues.	Do.
New Jersey	do	do	do	do	Reciprocity; 15 days.	do	do	do	do	Statute and motor vehicle commission.
New Mexico	Secretary of state	do	None	Must be 14 years old.	30 days	Net State and county road work.	do	do	None	Statute and local ordinance.
New York	do	Annual, Feb. 1.	All operators, annual, Feb. 1.	Chauffeur, examination.	Reciprocity.	State and local road work.[3]	75 per cent gross.	25 per cent gross.	Maintenance of State roads.	Statute, State highway commission, and local ordinance.
North Carolina.	do	Annual, July 1.	None	Must be 16 years of age.	Reciprocity to 60 days.	State road fund.	All net	None	None	Statute and local ordinance.
North Dakota.	Motor vehicle registration department.	Annual, Jan. 1.	do		No limit	Net to State and county road work.	One-half	One-half	do	Do.
Ohio	Secretary of state	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	do	State and local road maintenance.	do	do	do	Statute, State highway department, and local ordinance.
Oklahoma	Department of highways.	do	None		Reciprocity.	10 per cent appropriated for State highway department; 90 per cent county road work.	All		All	Statute and local ordinance.
Oregon	Secretary of state	do	Chauffeur, annual, Jan. 1.	Must be 16 years of age; no examination.	do	Net to State and county road work.	Three-fourths.	One-fourth	County road fund.	Do.
Pennsylvania.	State highway department.	do	do	Affidavits as to competency.	Reciprocity.	State and State-aid road work.	All gross	None	Certain ones locally.	Do.
Rhode Island	State board of public roads.	do	All operators, annual from date.	Examination, all operators.	Reciprocity 10 days.	Maintenance State roads.	All net	do	Same as registration revenues.	State board of public roads statute, and local ordinance.
South Carolina.	State highway department.	Annual, Jan. 1.			30 days	Maintenance highway department and county road work.	20 per cent	80 per cent	None	Statute and local ordinance.
South Dakota	Secretary of state through county treasurer.	do		Must be 15 years old.	Reciprocity.	90 per cent county road work.	None	90 per cent	do	Do.

[1] Must first set aside amount necessary to finance State highway bonds.
[3] Does not apply to revenue collected within New York City, one-half of which goes to the city general fund.

TABLE IV. Administrative provisions in force January 1, 1920, affecting motor-vehicle registrations, licenses, and revenues—Continued.

State.	Registration and licenses.					Revenues from registrations and licenses.				
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Nonresidents' exemption.	Applied to—	Proportion expended for roads under supervision of—		Revenues from fines and penalties, applied to roads.	Traffic regulations made by—
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
Tennessee	State department of highways through county clerk.	Annual, Jan. 1.			30 days	Net to State and county road work.	All net		Same as registration revenues.	Statute and local ordinance.
Texas	State highway department through county tax collector.	do	Chauffeur, annual, Jan. 1.	Must be 18 years of age.	90 days	Net to State and county highway funds.	50 per cent	50 per cent	County road work.	Do.
Utah	Secretary of state	Annual, Mar. 1.	do	No examination.	30 days	Motor vehicle registration fund.	All net [4]	None	None	Do.
Vermont	do	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination, chauffeur.	Reciprocity.	State maintenance fund.	do	do	do	Do.
Virginia	Secretary of commonwealth.	do	Chauffeur, annual, Jan. 1.	Certificate of competency.	2 periods of 7 days each.	Net to construction and maintenance of State roads.	do	do	do	Do.
Washington	Secretary of state through county auditor.	Annual, Mar. 1.	None	Operators must be 15 years of age, chauffeurs 21.	90 days	Net to permament highway fund for maintenance and construction.	None	All net	Same as registration revenues.	Do.
West Virginia	State road commission.	Annual, Jan. 1.	Chauffeur, annual, Jan. 1.	Must be 14 years of age.	Reciprocity.	State road fund	All	None	None	Do.
Wisconsin	Secretary of state	do	None	Must be 16 years of age.[5]	do	Net to State highway fund and county road work.	75 per cent net.	25 per cent net.	do	Do.
Wyoming	do	do	do	Must be 15 years of age.	Reciprocity to 90 days.	80 per cent to county.	None	None	do	Statute.

[4] To pay interest and sinking fund on $2,000,000 State road bond.

[5] Drivers of cars operating for hire may be licensed by municipalities.

NORTH CAROLINA WORK PROGRESSING DESPITE HIGH MATERIALS COST.

The State Highway Commission of North Carolina is rapidly pushing the construction of hard surfaced roads throughout the state.

At present 109 miles of road of this type are under construction. In all, 37 projects are under consideration, representing 349 miles, of these 240 are to be built of gravel sand and other material. The 109 miles, however, do not include all the hard surfaced construction which is contemplated, but simply that which is under way.

In spite of the high costs of materials, the commission is pushing construction work, and hopes to practically complete 200 miles of hard surfaced roads within 10 months. Construction is delayed because of the fact that quarry stone which used to be $1.50 crushed and loaded at the quarry has now risen to $2.50 and $3.

PURCHASE TURNPIKES.

The Pennsylvania State highway department, jointly with the counties in which they are located, has purchased three turnpikes having an aggregate of 16.6 miles, and converted them into free highways. The three cost $114,800, half of which was paid by the State.

TREES ALONG THE ROADS.

The Milwaukee County (Wis.) Park Commission is ready to prepare plans for planting trees along from 3 to 5 miles of the county's principal highways in 1921, and to proceed at that rate until the county is completely covered. Before the work can be undertaken, however, it will be necessary to broaden the county arterial highways to the width which will be demanded by the traffic of future years, so the trees can be permanently placed. The chairman of the park commission has requested the cooperation of the State highway commission in working out a plan for wider roads in the county.

BONDS ARE NOT SELLING.

State Highway Engineer Edy, of Montana, says chambers of commerce and bankers are being appealed to in the hope that county road bonds can be sold in sufficient amounts to avoid even the temporary abandonment of the road-building program in that State. Since February 1 contracts for more than $2,000,000 worth of road work have been let, while about $500,000 of the 1919 contracts remain uncompleted. This is only half the program for the year, and unless counties are able to dispose of bonds voted last fall it will be impossible to finance the projects.

FEDERAL CONTROL OF BRIDGES OVER OUR NAVIGABLE STREAMS.

By G. B. PILLSBURY, Colonel of Engineers, U. S. Army.

NAVIGABLE streams have, from the earliest days, been recognized by the law as highways of commerce over which the public has the right of free and unimpaired use. They may be occupied and obstructed by bridges, or otherwise, only by authority of the supreme legislative body having jurisdiction over them. Their status is the same, in this respect, as that of the public highways on land. This status is not always realized. A road is directly used by all citizens, and every member of the community is personally affected if it is encroached upon. Necessarily, but few of our citizens are vessel owners. On many of our navigable streams traffic by water has been diverted to rail or road, and the interest of the great mass of the people in water transportation is not obvious, however important it may indirectly be to them. Many look with impatience on the restrictions made to the obstruction of navigable waters. These restrictions are, however, based on the fundamental law, and, wisely administered, are essential to the best interests of the country at large.

The term "navigable waters of the United States" is used in legal terminology to designate those streams and other channels over which commerce is or may be carried on between States or with foreign countries. Under the interstate-commerce clause of the Constitution, the control over these waters, so far as concerns the public right of navigation, is vested in Congress. It may be observed that most of the navigable rivers in this country are "navigable waters of the United States," since nearly all rivers form, with connecting waters and with the sea, a continuous navigation system between States. Lakes lying wholly within a State, with no navigable outlet, and, in rare cases, the isolated navigable portions of some rivers wholly within a State, are navigable waters of the State, over which the Federal Government has no control.

THE CONSENT OF CONGRESS.

Congress has provided, in a law passed in 1899 (sec. 9 of the river and harbor act of Mar. 3, 1899, 30 Stat. L., 1150), that it is unlawful to build or commence the building of any bridge over any navigable waters of the United States until the consent of Congress has been obtained, and the location and plans have been duly approved by designated Federal officials, unless the navigable portions of the river lie wholly within the limits of a single State, in which case the bridge may be constructed under the authority of the legislature of that State, but the location and plans must still be approved by the Federal officials. As the work done by the Federal Government for the improvement of rivers and harbors have, from their inception, been executed by the Engineer Bureau of the War Department, the administration of the laws for the protection and preservation of navigable waters of the United States has been placed under that bureau, and the officers designated by Congress to approve plans for bridges are the Chief of Engineers, who is the head of that bureau, and the Secretary of War.

The earlier acts of Congress authorizing the construction of bridges specified, in considerable detail, the conditions under which the grant of authority was made. As these conditions were, in general, uniform in nature, an act known as the general bridge act was passed March 23, 1906, specifying the conditions to be met in the construction of all bridges thereafter authorized by Congress. Since the passage of that act, the special acts of Congress authorizing the construction of bridges are usually of very brief and simple form. The provisions of the general bridge act do not apply to bridges erected, under authority of a State, over a river the navigable portions of which lie wholly within the State.

PROVISIONS OF GENERAL LAW.

The principal provisions of the general bridge act are that every bridge subject to its terms shall be recognized and known as a post route; that charges to the United States for the transportation of mails, troops, and munitions of war, shall not exceed the rate per mile paid for transportation over the approach routes; that the United States shall have the right to construct, maintain, and repair telegraph and telephone lines across and upon the bridge without charge; that equal privileges in the use of the bridge and its approaches shall be granted to all telegraph and telephone companies; that if the structure is a railroad bridge, all railroad companies shall be entitled to equal privileges relative to the passage of trains or cars upon payment of a reasonable compensation; that if tolls are charged the rates may be prescribed by the Secretary of War; and that if the congressional act authorizing the bridge does not specify a time for beginning and completing the structure, the authority shall be null and void unless the actual construction of the bridge is begun within one year and completed within three years from the date of the passage of that act.

Bridges crossing the Mississippi and Ohio Rivers and certain other waterways of less importance, the Harlem, the Kanawha, the Maquoketa, and the

Illinois and Mississippi Canal are governed by special provisions of the Federal law, enacted for these particular streams at different times.

In addition to the laws relating to the construction of bridges, other provisions of the Federal statutes provide for their alteration when necessary in the interests of navigation. The law on this subject is found in section 18 of the river and harbor act of March 3, 1899 (30 Stat. L., 1153), and provides, in effect, that whenever the Secretary of War has good reason to believe that a bridge, whenever constructed, is an unreasonable obstruction to navigation, he shall, after giving the owners a reasonable opportunity to be heard, require that necessary changes be made at the expense of the owners. While this law may appear drastic, and perhaps unfair to the owners of a bridge constructed in good faith in accordance with approved plans, it must be recollected that the right of navigation to the use of the stream is paramount. Alterations to bridges are in fact required only when their necessity in the interests of navigation is very thoroughly established. Another provision of the law (sec. 2 of the river and harbor act of Aug. 11, 1888) provides in effect that whenever complaint is made to the Secretary of War that the current of navigable rivers has been deflected from its natural course by bridge piers or abutments so as to cause caving of banks or otherwise cause serious damage or danger to property, he shall after due inquiry, cause the owners of the bridge to repair the damage or prevent the danger. This last provision of law is very rarely invoked.

The Federal laws relating to the construction of bridges are published in a pamphlet form, and a copy may be secured on application to any district engineer of the Engineer Department at large.

PROCEDURE IN EACH CASE.

For the execution of works of improvement on rivers and harbors, and for the administration of the laws for the protection and preservation of the navigable waters of the United States, the country is divided into some 40 Engineer districts, each in charge of a district engineer, who is usually an officer of the Corps of Engineers of the Army. The Engineer districts are grouped into 10 divisions, each having a division engineer, an officer of long experience, whose duties include, among other things, the review of recommendations made by district engineers.

All plans for bridges across navigable waters are examined and reported on, in the first instance, by the district engineer in charge of the locality, who confers with the parties applying for approval as may be necessary, holds, in the usual case, a public hearing on the application, and sees that the application and plans are in due form. He forwards the application and plans to the division engineer with his recommendations. The division engineer reviews them and submits them, with his views, to the Chief of Engineers. If the proposed bridge affords sufficient facilities for navigation, and if the papers show that its construction has the necessary legislative authority, the Chief of Engineers then approves them and submits them to the Secretary of War. After a review of the legal aspects of the case by the Judge Advocate General of the Army, his legal adviser, the plans are approved by the Secretary of War and a copy of the instrument of approval is furnished the applicant. Variations from the general procedure occur in the case of applications for bridges over the Ohio and Kanawha Rivers, where, under the special Federal law relating to these rivers, the plans must be passed upon by a board of engineer officers.

WHAT A NAVIGABLE STREAM IS.

If a bridge is to be constructed, the first question to be determined, therefore, is whether the stream is navigable water of the United States. If the river is actually used for commercial navigation, no matter how small in importance, there is, of course, no doubt about its status. It is a navigable water of the United States unless it falls within the very limited number of navigable streams having no navigable connection with waters outside of the State. It may be observed that the mere existence of occasional barriers in the way of rapids, falls, etc., which cannot in their natural condition be passed by vessels, does not destroy the navigable connection, for such barriers may be overcome by suitable works. A stream may, however, be navigable, even though it does not happen to be navigated at the present time. In a leading case, the courts have held:

> The true test of the navigability of a stream does not depend upon the manner or mode by which commerce is or may be conducted, nor upon the difficulties attending navigation. If this were so, the public would be deprived of the use of many of the large rivers of the country over which rafts of lumber of great value are constantly taken to market. It would be a narrow rule to hold that in this country, unless a river was capable of being navigated by steam or sail vessels, it could not be treated as a public highway.
>
> The capability of use by the public for purposes of transportation and commerce affords the true criterion of the navigability of a river, rather than the extent and manner of that use. If it be capable in its natural state of being used for purposes of commerce, no matter in what mode the commerce may be conducted, whether in vessels propelled by steam, wind, oars, or poles, the stream is navigable in fact and comes in law a public highway.
>
> It is not to be understood, however, that every ditch or inlet in which the tide ebbs and flows, nor every small creek in which a fishing skiff or gunning canoe can be made to float at high water, is a navigable highway; but to give it the character of a navigable stream it must be generally and commonly useful to some purpose of trade or agriculture.

Certain rivers, some 20 in number, have been declared by Congress to be either in whole or in part nonnavigable. The effect of this legislation is to remove from them the operation of the Federal laws relating to the preservation and protection of navigable waters as concerns the construction of bridges and otherwise.

It may be observed that the question of navigability is not one that can be settled by the mere dictum of an executive officer of the Federal Government. It is a question of fact which, in the last resort, can be determined only by the courts. However, the question is not as difficult a one as is sometimes fancied. A reasonable inquiry in the locality will usually settle the point.

STREAM IN SINGLE STATE.

The question of the navigability of the stream being determined, the next point is whether the navigable portions of the river lie wholly within a single State or whether they extend beyond a single State. This question is readily settled.

If the navigable portions of the river extend beyond the limits of a single State a special act of Congress is necessary to authorize the construction of the bridge. Such an act should be secured through the Representative of the locality in Congress. It may not be out of place to point out that the act authorizing the construction of the bridge should be as simple and direct as possible, as the applicant must furnish proof that all the conditions recited in the act have been fulfilled. Thus, where an act authorizes the construction of a bridge across a certain river and recited that the bridge was on the route of a certain-named continental highway, it was held that the applicant must furnish proof that the proposed bridge was on the route of that highway; and the papers were returned to him for that purpose, with considerable consequent delay.

If the navigable portions of the river lie wholly within a single State, the authority of the State legislature is sufficient. Most States have general laws authorizing the construction of bridges by county boards, etc., and the charters of public service corporations often grant authority for such construction. A special act of a State legislature is, therefore, often unnecessary.

REQUIREMENTS IN DESIGN.

The legal aspects of the case having been settled, the question next arises as to the requirements to be met in the design of the bridge to satisfactorily meet the needs of navigation. These requirements include the location of the bridge with respect to the navigable channel; the spacing of the piers; the clear height of the structure above high and low water, and the length and character of draw span, if any, to be provided. The requirements necessarily differ with each waterway, and sometimes in different parts of the same waterway. All depends on the character and extent of existing navigation, and that reasonably prospective, due attention being given that suitable provision is made for passing drift and flood flows. The district engineer should be freely consulted. He will be able to advise the applicant on what the requirements of navigation are, and it will be but very rarely that a change will be necessary on account of objections brought out at the public hearing.

The working up of the design of a structure conforming to the navigation requirements and suitable for the traffic that will pass over it, rests wholly with the party building the bridge. The design in all matters, except the clearances for navigation, is not a matter of concern to the Department, except in those rare cases when the law authorizing the construction contains specific requirements as to the design and construction.

The final step is the preparation of the plans for the approval of the Department and of the application for approval, supported by the necessary evidence of legislative authority.

PREPARATION OF PLANS.

The plans required include a map showing the location of the bridge, on which, as a rule, the waterway is to be shown for a distance of 1 mile above and 1 mile below the structure; and outline plan and elevation of the bridge showing the clearances for navigation. Elaborate plans showing the details are neither required or desired. Small and compact plans are preferred. Four copies, in all, of the maps and plans are required, three for file in the various Government offices concerned, and one for the applicant after approval. It is essential that one set of the maps and plans be on tracing linen, or otherwise prepared to form a permanent and readily reproduceable record.

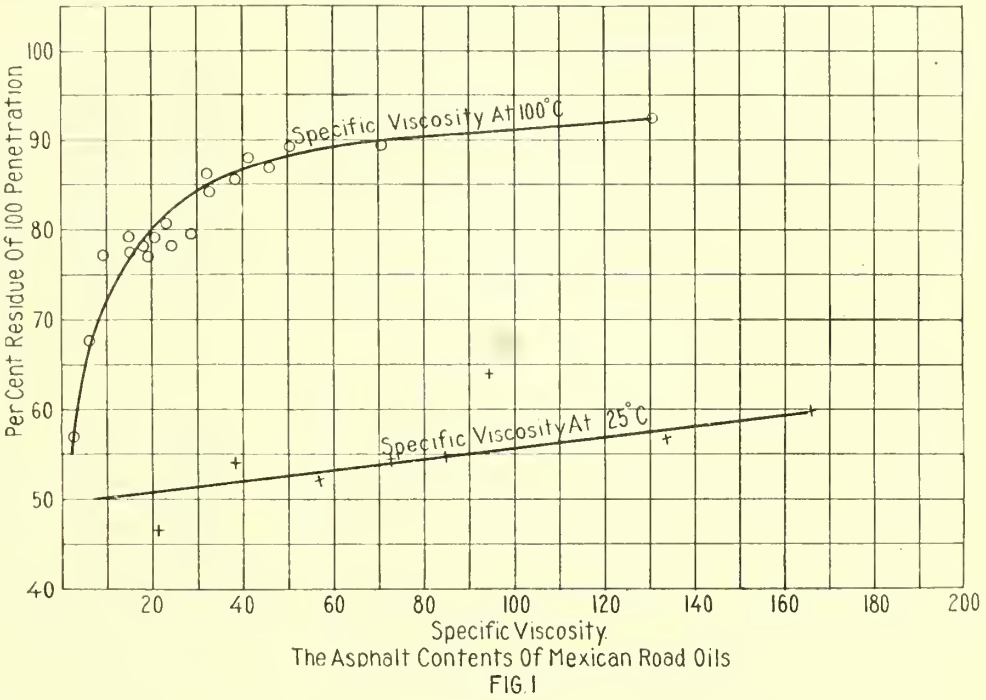
A printed form is provided for the letter of application. Accompanying it, the applicant must furnish the papers necessary to show the legal authority for the building of the bridge, and to identify the applicant as the party to whom this authority has been granted. It is unnecessary to detail here the papers necessary to this end. They are described on the printed form, and further explanation of the requirements in any particular case may be secured from the district engineer.

In summary, when the construction of a bridge across a navigable waterway is to be undertaken, those proposing to construct it should confer with the district engineer in charge of the locality at as early a date as is possible, to settle the questions of the facilities to be provided for navigation, and to post themselves on the requirements of law that must be met. The preparation of the papers in due form, the advertisement of the public hearing on the application, and the consideration by the department of the case, necessarily consume some time, and it is most important that the matter of approval be taken in hand in due season, as the law forbids the commencement of the construction until the plans are duly approved.

THE "ASPHALT CONTENT" OF ROAD OILS.

By B. A. Anderton and D. G. Taylor, Division of Tests, U. S. Bureau of Public Roads. [1]

THE grading of asphaltic road oils on the basis of the percentage of asphalt contained in them is still in extensive use as a means of differentiating between various types of oils—that is, as between their inherent nature and consistency. Notwithstanding that there are obvious difficulties in making the test, and that its value has been for some time severely criticised, a conference of State highway testing engineers and chemists, held in Washington in 1917, deemed the test of such extensive use as to warrant including it as an alternate requirement in forms of specifications drawn up for road oils. The method of making the test was also considered, and in the report [2] of the conference the recommended procedure to be followed is given as follows:



The Asphalt Contents Of Mexican Road Oils
FIG. 1

PERCENTAGE OF RESIDUE OF PENETRATION.

Fifty grams of the oil are placed in a 3-ounce deep, seamless tin box; the box is placed in a sand bath and heated over a Bunsen burner. A thermometer is suspended in the oil, the bulb not touching the bottom of the box. The temperature of the oil is kept at from 249° C. to 260° C. (480° F. to 500° F.), and the oil is stirred from time to time with the thermometer to prevent overheating in any part. Depending upon the nature of the oil, as usually indicated by its flash, consistency at 25° C. (77° F.), and the specific gravity, the operator can with experience tell about what percentage it will be necessary to evaporate before cooling and taking a penetration of the residue. It is sometimes necessary to make several trials before the desired result is obtained. When the required penetration is reached the residue left from evaporation is weighed and its percentage of the original sample taken is computed.

The Bureau of Public Roads, with a desire to investigate how closely the various characteristics of a sample would indicate the percentage of residue of 100 penetration, as suggested in this description of the test, has made a large number of determinations following the procedure given as closely as possible. From the results of this work, we will attempt in this communication to present the most significant indications as to the value of the test for asphalt content. We may divide the selected tests into three groups as follows:

(1.) Residual petroleums, asphaltic petroleums, and oil asphalt cut backs having different specific gravities and consistencies; (2) a series of Mexican products having specific gravities ranging from 0.935 to 1.024 and specific viscosities at 100° C. ranging from 2.4 to 131 and a series of Mexican products having sepcific gravities ranging from 0.935 to 0.965, with specific viscosities at 25° C. ranging from 20.4 to 165, and with flash points ranging from 42 to 105; (3) a selected sample upon which numerous tests were made to discover effects, if any, that varying conditions might have upon the results. In all the tests with the exception of those under No. 1 it was desired to obtain a residue that would yield a penetration of 100.

GROUP NO. 1 TESTS.

In the tests of group No. 1 it was found that no general relation could be discovered between the percentage of asphalt and ordinary test characteristics of the sample. The source of the oil has a great influence on the results of the test; for instance, two oils from different sources when heated for the same

[1] Paper read before the American Society for Testing Materials, Asbury Park, N. J.
[2] Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials, Bul. No. 555, U. S. Department of Agriculture, Washington, D. C., Nov. 25, 1917.

length of time will give entirely different amounts of residue, notwithstanding the fact that they have practically the same consistency or specific gravity; and when these samples have been heated until the residues show the same penetration they do not necessarily have the same percentage of residue. This was shown when tests of Mexican oils were compared with tests of other oils. Some typical results are given in Table I.

TABLE I.—*Comparison of tests made on Mexican oils with tests made on oils from other sources.*

Type of oil.	Specific gravity.	Specific viscosity.	Time heated at 249° to 260° C.	Percentage of residue.	Penetration of residue.
		° C.	Min.		
Mexican	0.965	165.0-25	45	59.5	100
Texas	.940	163.6-25	95	69.1	100
Mexican	1.004	24.4-100	45	78.4	103
Trinidad	1.004	29.1-100	90	83.6	103
Mexican	.943	94.8-25	35	64.2	97
Mid-continent	1.031	99.0-25	50	54.4	102
Mexican	.991	16.8-100	30	78.0	97
California	.994	17.0-100	120	76.4	100

A comparison of the Mexican product with the Texas product shows that when the samples had been heated until they gave the same penetration the difference in the percentage of their residues was 9.6. A comparison of the Mexican product with the Trinidad product shows that when the samples had been heated until they gave the same penetration the difference in the percentage of their residues was 5.2. With the Mid-Continent residual it is shown that a much lower percentage of asphalt results, although the original oil was slightly heavier, and the residue somewhat softer. In the last case a comparison of the Mexican product with the California product shows that there was only a slight difference in the percentage of their residues. It may be especially noted that the evaporation took place much more rapidly with the Mexican samples, and it necessarily required a shorter time to gain residues yielding a penetration of approximately 100 with such oils.

GROUP NO. 3 TESTS.

The results of tests made on materials stated under group No. 2 are given in Table II.

TABLE II.—*Percentage of residue of Mexican oils.*

SPECIFIC VISCOSITY AT 100° C.

Serial No.	Specific gravity.	Specific viscosity.	Percentage insoluble in 86° B. naphtha.	Flash point.	Percentage of residue.	Penetration of residue.
				° C.		
14104	0.935	2.4	13.8	70	[1] 56.8	100
14044	.961	6.2	17.5	98	67.6	78
12027	.995	19.8	19.6	95	77.0	90
10460	.990	9.4	17.3	100	77.2	91
10491	.991	16.8	19.4	60	78.0	97

TABLE II.—*Percentage of residue of Mexican oils*—Continued.

SPECIFIC VISCOSITY AT 100° C.

Serial No.	Specific gravity.	Special viscosity	Percentage insoluble in 86° B. naphtha	Flash point.	Percentage of residue.	Penetration of residue.
				° C.		
11147	.995	17.5	20.1	.....	78.0	95
10477	.996	18.6	18.6	75	78.4	99
11164	1.004	24.4	20.4	.....	78.4	102
10475	.993	15.7	19.4	70	79.0	97
11154	1.005	20.6	17.3	.....	79.2	98
11630	1.001	29.1	20.6	.....	79.6	100
11093	1.002	22.5	.....	.....	80.6	100
10500	1.013	32.5	.....	.....	84.4	100
14106	.991	38.7	20.0	206	85.8	100
14045	1.004	32.3	22.0	190	86.2	102
14126	.998	46.0	.....	204	87.2	92
12326	.999	41.6	20.9	.....	87.8	100
12392	1.008	51.7	.....	.....	[1] 89.0	100
10266	1.015	70.9	21.7	.....	[1] 89.3	100
12413	1.024	131.0	22.8	.....	[1] 92.4	100

SPECIFIC VISCOSITY AT 25° C.

10636	0.936	20.4	.....	.....	46.6	97
14042	.954	57.0	13.3	100	52.4	80
12026	.943	38.6	13.1	45	54.2	90
14043	.938	72.9	13.3	100	54.4	87
12391	.936	85.0	13.4	105	54.8	105
14104	.935	133.8	13.8	70	[1] 56.8	100
11810	.965	165.0	16.0	65	[1] 59.5	100
11766	.943	94.8	14.3	42	64.2	97

[1] Interpolated from results of two tests, one having a slightly higher residue and the other a slightly lower residue.

Generally speaking, it was found that an approximate relation exists between the percentage of residue of 100 penetration and between the consistency, the specific gravity, the flash point, and the percentage insoluble in 86° B. naphtha. Of these relations the one involving the consistency of the material is probably the best aid in estimating the asphalt content of an oil. From the plot between the percentage of asphalt and the specific viscosity shown in figure 1, however, it will be noted that an estimate of the percentage of asphalt of 100 penetration can be made only within rather wide limits.

Thus, judging from this graph, the percentage necessary to be volatilized from a sample having a specific viscosity at 100° C. ranging up to 60 may be inferred within not less than 3 per cent.

GROUP NO. 3 TESTS.

In group No. 3 the material selected was a Mexican asphalt having an original penetration of 177. First, six samples were taken and tested in the regular way. The first sample was heated for five minutes at the required temperature (249 to 260° C.) and each successive sample was heated five minutes longer than the preceding one. Samples numbered 2 and 3 were reheated at the required temperature. Then two additional samples, numbered 7 and 8, were heated for 20 minutes at the required temperature, number 7 being stirred very frequently and number 8 continuously. Penetration tests were made on the residues from the above samples with the results shown in Table III.

TABLE III.—*Tests made to note results from heating material different lengths of time.*

Sample No.	Time heated at 249° to 260° C.	Percentage of residue.	Penetration of residue.
1	5 minutes	99.6	150
3	15 minutes	97.6	133
2	10 minutes	97.2	129
5	25 minutes	96.4	105
4	20 minutes	96.0	100
6	30 minutes	95.2	96
	EFFECT OF REHEATING SAMPLES NOS. 2 AND 3.		
2	10 minutes	97.2	129
	5 minutes additional	96.0	100
	5 minutes additional	95.0	89
3	15 minutes	97.6	133
	5 minutes additional	96.4	102
	EFFECT OF STIRRING.		
[1] 7	20 minutes	97.6	120
	5 minutes additional	96.4	104
[2] 8	20 minutes	97.0	114

[1] Stirred very frequently. [2] Stirred continuously.

It will be noted that the loss is not proportional to the time of heating. If the test made on sample No. 4 is compared with that made on sample No. 2, it will be seen that a residue of 96 per cent gave a penetration of 100, and that when sample No. 2 was reheated for five minutes at the required temperature that a residue of 96 per cent was obtained, also yielding a penetration of 100. Again, if the tests made on samples Nos. 3, 5, and 7 are compared it will be seen that their final residues are the same (96.4 per cent), although sample No. 3 was reheated and sample No. 7 was both reheated and subjected to excessive stirring. The penetration tests on these residues showed a maximum difference of only three points. This would seem to indicate that intermittent heating or increased stirring did not affect the results to any great extent, although it must be conceded that results with such a viscous material and having such low losses are not conclusive as applied to fluid road oils.

CONCLUSIONS.

As a result of the work carried out as above described, certain conclusions are suggested to us:

1. That with a given type of oil, the consistency will indicate the percentage of asphalt.

2. That the time necessary to secure the required residue will vary within wide limits, and can not be readily estimated while making the test as described.

3. That the effect of stirring is indicated to be less than that of other factors difficult to control, which affect the results.

There are many features of the test which may be adversely criticized. Among these may be enumerated the following: The tedious and long continued attention necessary to secure even approximate results; the difficulty in maintaining the required temperature, which is of great importance to secure concordant results; the fact that the changes taking place during heating are not understood and probably are not indicative of the changes in the oil while in service on the road. At best it is a "cut and try" method, and therefore can not be based on scientific principles of testing.

Summarizing our conclusions, it may be stated that it is our belief that the percentage of asphalt gives no additional information on the suitability of a road oil for a given purpose, which is not adequately shown by the results of other tests, better understood and at the present time well standardized.

BEAUTIFYING THE ROADS.

John A. Hazlewood, chairman of the Wisconsin State Highway Commission, in an address at the rural planning school of that State discussed the ornamentation and beautifying of highways. He said, "It has long been a recognized fact that the time would come when a systematic and well-defined plan for the planting of trees and shrubs along our highways would be practicable. It will pay to do so. It can be shown by convincing arguments that trees and shrubs, if properly planted and maintained along highways, may be of true service in practicable ways as well as in beautifying the roadside. The pleasure resulting from one's passing along beneath the arches formed by rows of elms and maples should be sufficient reason for a continuance of the work.

"There are two ways in which trees and shrubs should be planted along highways. The first type may be said to exist where the trees, shrubs, and flowers form the element of the picture with the roadway as the central feature. This type of planting, has been used to advantage where the scenery along the roadside is ugly and monotonous. Many miles of ugly roadside could thus be made attractive by bringing one's interest into the road itself.

"The second type may be called the 'open type,' where the woods, meadows, fields, and distant landscape form the composition of the picture, with the trees so arranged as to afford frames for these delightful vistas and thus make the roadside more charming. Very rarely is there a highway of any length that does not, to some extent, offer the opportunity for both types of planting."

FOR MORE BONDS.

It has developed that the $4,000,000 worth of road bonds voted by Maricopa County, Ariz., a year or more ago will build only about one-half the roads contemplated at the time of the election. There is now a movement favoring the issue of an additional $4,500,000 worth.

GALVANIZED CULVERTS.

By L. G. Carmick, Assistant Chemist, Bureau of Public Roads.

AMONG the many problems that confront the highway engineer, and one that frequently causes perplexity, is the selection of the proper type of culvert. Many sorts may be, and have been used, but in most cases the matter is practically limited to a choice between concrete and galvanized iron or steel. The concrete culvert is almost indefinitely permanent in most localities, if properly constructed, but is expensive and requires time to build. Galvanized metal, though undoubtedly open to objection, is very extensively used, especially for small culverts, because of its relative cheapness, availability and convenience. It therefore becomes a matter of much importance to secure the best possible type of galvanized metal.

At present we do not know just how long a galvanized culvert should last. Probably we do not yet know how to select the best type either. Our theories on the corrosion of iron are now in process of development for it is not more than 15 years ago that the subject was taken up in earnest and became a research problem of major importance. And while considerable progress has been made no one at all familiar with it supposes for a moment that the last word on the subject has been spoken. The life of a metal culvert depends on quite a number of different factors, some of which have to do with the culvert itself and others with the conditions under which it is used. It is not proposed to discuss all of these factors here, but simply to deal with the practical aspects of one of them—the zinc, or as it is usually called, spelter coating.

THE SPELTER COATING.

Having in mind the sort of material now in general use we may say that, roughly speaking, the duration of the spelter coating will be about three-quarters of the life of the culvert. It is the present practice of the Bureau of Public Roads and of many of the State highway departments to specify that culvert sheets shall carry at least 2 ounces of spelter per square foot. This includes both sides of the sheet, so that each square foot of actual surface must have at least 1 ounce of spelter.

To determine whether or not this amount is present, it is customary to make a chemical analysis of one or more small pieces cut at random from the culverts. This is what is frequently referred to as a spot test. The test pieces are usually 2 by 2 inches or $2\frac{1}{4}$ by $2\frac{1}{4}$ inches and are of course very small in comparison to a culvert. Frequently one or two such pieces are sent to a laboratory as representative of a shipment of culverts, which may mean as much as a carload. In view of the well-known fact that the coating can not be applied with a high degree of uniformity, it has been claimed that such a system of testing is inadequate and unfair.

It was partly for the purpose of determining what value could be attached to such tests that the Bureau of Public Roads recently undertook an investigation of the matter.

VALUE OF USUAL TESTING SYSTEM.

Four of the principal mills producing culvert sheet were visited and at each of them the management extended great courtesy and every facility that could further the investigation.

At each mill a considerable number of sheets were weighed with accuracy after pickling and drying, and were then galvanized and weighed again. In this way the exact amount of spelter on each sheet was ascertained. The sheets were generally from 80 to 120 inches long and 27 inches wide. All of them were either 14 or 16 gauge. From each of these sheets a strip $1\frac{1}{2}$ inches wide was cut off from each end and discarded. A sample strip 3 inches wide was then cut off from each end and another such sample strip was taken from the middle. These strips were sent to Washington, and there three test pieces were cut from each strip. In this way nine samples were taken from each of the original sheets. All of the test pieces were cut to $2\frac{1}{4}$ by $2\frac{1}{4}$ inch size to an accuracy of 0.01 inch in a milling machine, and were then analyzed.

There are two principal methods for the determination of spelter coating. One consists in immersing the test pieces in a strong solution of lead acetate (400 grams to the liter) which removes the zinc and deposits an equivalent amount of lead in a very loosely adherent form. The other method consists in immersing the pieces in concentrated hydrochloric acid to which has been added a small quantity of a solution of antimony chloride. As this seemed a good opportunity to test the relative merits of the two methods, both were used as indicated in connection with the data given below. At first, when the antimony-hydrochloric acid method was used, the pieces were immersed for just one minute as is usually prescribed. But this seemed to give somewhat high results, so the time was shortened, first to 45 seconds and then to 30 seconds, with an apparent improvement in the accuracy of the results. At any rate it was evident that half a minute was ample time to remove all of the spelter.

RESULTS OF THE TESTS.

The results obtained by the analysis of the samples are given below. The four mills at which the sheets were galvanized will be designated by the numerals I, II, III, and IV. The expression "actual average" means the average coating on the sheets as determined by weighing them before and after galvanizing at the mills. Extreme variation is the difference between the highest and lowest of the nine tests from one sheet.

MILL I.

SHEET 1.

	Front.	Middle.	Back.
A	3.097	3.125	3.009
B	3.011	3.041	3.395
C	2.931	3.227	3.152

Average of tests..... 3.119
Actual average..... 2.830
Extreme variation..... .464
Antimony-acid method, one minute's immersion.

SHEET 2.

	Front.	Middle.	Back.
A	2.525	2.528	2.387
B	2.368	2.150	2.236
C	2.633	2.233	2.980

Average of tests..... 2.448
Actual average..... 2.190
Extreme variation..... .830
Antimony-acid method, one minute's immersion.

SHEET 8.

	Front.	Middle.	Back.
A	2.355	2.362	2.469
B	2.612	1.923	2.351
C	2.432	2.475	2.501

Average of tests..... 2.386
Actual average..... 1.970
Extreme variation..... .689
Antimony-acid method, one minute's immersion.

SHEET 10.

	Front.	Middle.	Back.
A	1.788	1.920	2.110
B	1.900	1.605	1.671
C	1.920	1.805	1.735

Average of tests..... 1.762
Actual average..... 1.690
Extreme variation..... .505
Lead acetate method.

SHEET 11.

	Front.	Middle.	Back.
A	1.920	1.970	1.781
B	2.151	1.724	1.865
C	2.369	2.094	1.926

Average of tests..... 1.978
Actual average..... 1.720
Extreme variation..... .645
Antimony-acid method, one minute's immersion.

SHEET 21.

	Front.	Middle.	Back.
A	1.849	1.696	1.865
B	2.054	2.123	2.092
C	1.880	1.747	2.151

Average of tests..... 1.939
Actual average..... 1.640
Extreme variation..... .455
Lead acetate method.

SHEET 22.

	Front.	Middle.	Back.
A	2.150	2.019	1.863
B	2.124	1.949	2.133
C	2.183	1.979	1.728

Average of tests..... 2.014
Actual average..... 1.800
Extreme variation..... .455
Antimony-acid method, 45 seconds' immersion.

SHEET 23.

	Front.	Middle.	Back.
A	2.499	2.225	2.615
B	2.671	2.396	2.209
C	2.648	2.360	1.943

Average of tests..... 2.396
Actual average..... 2.310
Extreme variation..... .728
Antimony-acid method, 30 seconds' immersion.

SHEET 27.

	Front.	Middle.	Back.
A	2.008	2.022	1.923
B	2.259	2.190	1.882
C	2.108	1.802	1.962

Average of tests..... 2.017
Actual average..... 1.980
Extreme variation..... .457
Antimony-acid method, 30 seconds' immersion.

MILL II.

SHEET 7.

	Front.	Middle.	Back.
A	2.062	2.019	1.828
B	2.000	1.678	1.956
C	1.850	1.733	1.996

Average of tests..... 1.902
Actual average..... 1.670
Extreme variation..... .385
Antimony-acid method, 30 seconds' immersion.

SHEET 9.

	Front.	Middle.	Back.
A	2.071	2.040	2.040
B	2.271	1.935	1.895
C	2.260	2.136	2.017

Average of tests..... 2.074
Actual average..... 1.960
Extreme variation..... .376
Lead acetate method.

SHEET 12.

	Front.	Middle.	Back.
A	2.537	2.430	2.463
B	2.324	2.383	2.291
C	2.259	2.541	2.256

Average of tests..... 2.387
Actual average..... 2.190
Extreme variation..... .285
Antimony-acid method, 30 seconds' immersion.

SHEET 15.

	Front.	Middle.	Back.
A	1.915	1.764	1.815
B	2.316	1.867	2.076
C	2.076	2.015	2.048

Average of tests..... 1.988
Actual average..... 1.790
Extreme variation..... .552
Antimony-acid method, 30 seconds' immersion.

SHEET 19.

	Front.	Middle.	Back.
A	2.270	1.970	2.389
B	2.315	1.880	1.212
C	2.198	2.110	2.076

Average of tests..... 2.040
Actual average..... 2.000
Extreme variation..... 1.177
Antimony-acid method, 30 seconds' immersion.

SHEET 20.

	Front.	Middle.	Back.
A	2.560	1.988	2.227
B	2.354	1.737	2.047
C	2.407	2.234	2.192

Average of tests..... 2.194
Actual average..... 2.070
Extreme variation..... .823
Antimony-acid method, 30 seconds' immersion.

MILL III.

SHEET 5.

	Front.	Middle.	Back.
A	1.160	2.002	2.094
B	2.057	1.856	1.956
C	2.048	1.913	1.950

Average of tests..... 1.892
Actual average..... 1.890
Extreme variation..... .934
Antimony-acid method, 30 seconds' immersion.

SHEET 6.

	Front.	Middle.	Back.
A	1.959	1.877	1.886
B	2.031	1.894	1.961
C	2.093	1.805	1.963

Average of tests..... 1.941
Actual average..... 1.810
Extreme variation..... .288
Lead acetate method.

SHEET 12.

	Front.	Middle.	Back.
A	2.141	1.989	2.102
B	2.286	2.016	2.052
C	2.128	1.972	2.133

Average of tests..... 2.091
Actual average..... 2.000
Extreme variation..... .314
Antimony-acid method, 30 seconds' immersion.

SHEET 13.

	Front.	Middle.	Back.
A	2.222	2.149	2.175
B	2.531	2.249	2.290
C	2.393	2.245	2.281

Average of tests..... 2.282
Actual average..... 2.260
Extreme variation..... .384
Antimony-acid method, 30 seconds' immersion.

SHEET 51.

	Front.	Middle.	Back.
A	2.011	1.994	1.958
B	2.325	2.046	2.084
C	2.081	2.039	2.127

Average of tests..... 2.074
Actual average..... 1.970
Extreme variation..... .367
Antimony-acid method, 30 seconds' immersion.

SHEET 57.

	Front.	Middle	Back.
A	2.018	1.849	1.980
B	2.160	2.005	2.016
C	1.556	1.987	1.953

Average of tests..... 1.947
Actual average..... 1.840
Extreme variation..... .604
Antimony-acid method, 30 seconds' immersion.

SHEET 59.

	Front.	Middle.	Back.
A	2.091	2.066	2.089
B	2.383	2.284	2.253
C	2.407	2.305	2.199

Average of tests..... 2.231
Actual average..... 2.200
Extreme variation..... .341

Antimony-acid method, 30 seconds' immersion.

MILL IV.

SHEET 4.

	Front.	Middle.	Back.
A	1.998	1.914	1.993
B	1.921	2.011	1.753
C	2.179	1.999	1.941

Average of tests..... 1.970
Actual average..... 1.990
Extreme variation..... .426

Antimony-acid method, 30 seconds' immersion.

SHEET 8.

	Front.	Middle.	Back.
A	2.192	2.121	2.071
B	2.171	2.302	1.994
C	2.061	1.993	2.121

Average of tests..... 2.114
Actual average..... 2.010
Extreme variation..... .309

Antimony-acid method, 30 seconds' immersion.

SHEET 9.

	Front.	Middle.	Back.
A	2.435	2.245	2.593
B	2.298	2.355	2.282
C	2.401	2.619	2.402

Average of tests..... 2.403
Actual average..... 2.300
Extreme variation..... .374

Antimony-acid method, 30 seconds' immersion.

SHEET 10.

	Front.	Middle.	Back.
A	2.267	2.206	2.501
B	2.282	2.212	2.418
C	2.524	2.315	2.405

Average of tests..... 2.314
Actual average..... 2.240
Extreme variation..... .418

Antimony-acid method, 30 seconds' immersion.

INSPECTION OF SHEETS AT MILL.

A study of these results reveals several points of interest. In the first place it is evident that there is a great lack of uniformity in the coating on different parts of a sheet. In fact, the variation may amount to as much as 50 per cent of the average for the sheet, or over 1 ounce. In general, however, it was not more than half of that, the average variation for the 26 sheets being 0.522. Furthermore, the practice at the various mills seems to be very much the same. This shows clearly how little reliance can be placed on the results from one or two small test pieces. In order to secure an adequate idea of the spelter coating on a shipment of culverts it would be necessary to take quite a large number of samples, and even then the question might be raised as to whether they were truly representative. Such thorough sampling as really seems necessary involves considerable work both in the field and in the laboratory, and of course works great injury to the culverts themselves.

It would be very much better if a system could be worked out whereby the sheets could be inspected at the mill, by weighing before and after galvanizing. Such inspection might consist of weighing and branding every sheet, or it might be found practicable to weigh an occasional sheet and certify shipments on the results of such tests. Any reasonable arrangement of this sort would be welcomed by the manufacturers and would obviously be of great advantage to highway engineers and contractors.

METHOD OF ANALYSIS TO BE USED.

However desirable a system of mill inspection may be, there seems no doubt that for the present, and at times, even when we have such a system, the "spot test" will be used. Therefore, in addition to care and thoroughness in sampling, it seems well to give some thought to the method of analysis to be used.

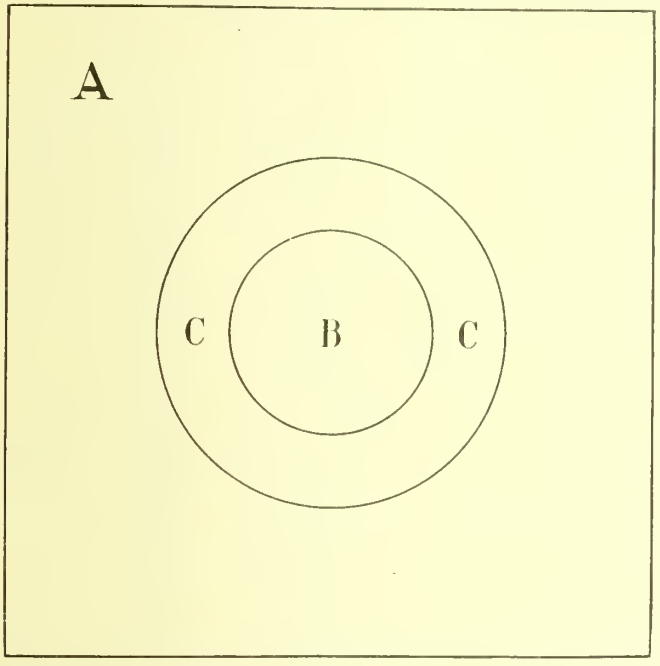
The hydrochloric acid-antimony chloride method is very quick and neat and it has been stated by many chemists that it is quite as accurate as the lead acetate method. Four sheets were analyzed by the acid method with one minute immersion as is usually prescribed. The average of these tests was 0.305 ounces higher than the actual average of the sheets. The time of immersion was then reduced to 45 seconds and this gave for one sheet an average of 0.214 above the actual. The time was then reduced to 30 seconds, and 17 sheets analyzed in this way gave an average of only 0.087 above the actual. For the purpose of comparison 4 sheets were done by the lead acetate method and these gave an average of 0.146 above the actual.

It is, of course, realized that this series of tests is too limited to serve as a basis for definite conclusions, and yet it is of interest to note that when the acid method was used with one minute immersions the results were much too high and that when the time was reduced to 30 seconds the results were remarkably accurate; more so, in fact, than those given by the lead acetate method. It would seem that these indications are worthy of careful study.

AMOUNT OF SPELTER PERMISSIBLE.

Another point to which attention was given while at the mills, was the amount of spelter that can be applied to sheets without danger of its cracking or peeling during corrugation and fabrication. This seemed to be of importance because of the claim made by some manufacturers that a coating much over 1.5 ounces was apt to be loosely adherent. It will perhaps be sufficient to state that pieces from the sheets discussed above and also a considerable number of others, all of which carried known weights of spelter, were corrugated and curved into 12 and 15 inch culverts. In the case of one sheet only was there sufficient flaking to justify an inspector in rejecting the culvert. That sheet carried 2.32 ounces of spelter, a rather heavy coating: and yet a number of

other sheets with quite as much, and in one case as high as 2.83, were fabricated without difficulty.



Hence there seems to be little reason for doubting that considerably more than 2 ounces per square foot may be safely applied It is not to be understood that the coatings were in every case free from cracks. In some cases very slight cracks were observed on the outside of the lap where the metal had been bent rather sharply, but these were not considered important.

Zinc being electropositive with respect to iron, exerts a protective action at a considerable distance. This is well illustrated by an experiment which is quite familiar in all laboratories where this subject has been studied. If a piece of steel, A, has a hole bored in it and this hole is filled with a plug of zinc, B, and the entire surface polished smooth and bright, it will be found that the steel in the immediate vicinity of the zinc, C, will remain bright even under the most severe conditions of exposure. This protected area will usually extend for about three-eighths of an inch from the edge of the zinc. If the plug had been of tin, copper, or any other metal electronegative with respect to iron, the reverse would be true and corrosion of the iron would be more marked in the vicinity of the plug than elsewhere. For this reason, the slightest cracks or pin-holes in tin-plate constitute defects of the most serious character, but in the case of zinc coating they are of less importance.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN APRIL, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Arizona	26	Yuma	23.900	Selected material	Apr. 26	$250,910.00	$125,455.00
Arkansas	84	Conway	14.150	Bituminous surface	Apr. 2	117,156.32	47,156.59
	62	Washington	18.280	Gravel	Apr. 6	35,493.37	15,500.00
	70	Searcy	17.540	Macadam	Apr. 7	101,970.00	40,000.00
	87	Pope	8.230	Bituminous	Apr. 2	112,150.19	50,000.00
	44	Lonoke	12.880	Gravel	Apr. 9	96,811.55	13,000.00
	79	Conway	8.250	Bituminous	Apr. 16	117,411.18	31,000.00
	73	Searcy		Bridges	Apr. 9	17,281.00	7,200.00
	43	Lincoln and Desha	2.050	Gravel	Apr. 24	22,579.92	7,700.00
	90	Nevada	16.360	Macadam	Apr. 26	143,280.55	68,000.00
	91	Arkansas	13.950	Warrenite	do	466,526.68	57,000.00
California	53	Mariposa	7.270	Earth	Apr. 2	623,252.30	165,112.00
	54	do	5.690	do	do	224,329.60	112,164.80
	55	San Diego	4.600	Concrete	Apr. 21	122,637.35	61,318.67
	56	Shasta	15.670	do	Apr. 24	376,200.00	188,100.00
Colorado	71	La Plata	12.005	Earth	Apr. 2	99,468.30	49,734.15
	68	Rio Grande	11.358	Gravel	Apr. 7	81,740.94	42,370.47
	58	Prowers	3.144	do	Apr. 12	30,986.78	15,493.39
	117	El Paso	0.932	Concrete	Apr. 26	49,780.50	18,640.00
Georgia	131	Jackson	7.150	Sand-clay	Apr. 2	67,201.10	33,600.55
	133	Troup		Bridge	Apr. 6	134,728.44	50,000.00
	135	Elbert	10.500	Topsoil	Apr. 7	57,805.00	25,000.00
Idaho	110	Morgan	4.626	Concrete	Apr. 14	[1] 86,815.30	[1] 43,058.03
	35	Caribou	3.830	Crushed rock	Apr. 3	47,935.80	23,967.90
	38	Butte	16.000	Gravel	do	90,000.00	30,000.00
	39	Lewis	4.270	Crushed rock	Apr. 2	55,999.35	20,000.00
	40	Washington	20.000	Earth	do	194,940.90	97,470.45
	41	Teton	9.750	Gravel	do	89,999.80	32,500.00
	46	Bonneville	2.710	Concrete or bituminous	Apr. 26	85,520.93	[2] 42,760.46
	21	do	3.540	do	do	[2] 85,520.94	[2] 42,760.47
Illinois	12	Edgar and Clark	28.860	Concrete and brick	Apr. 21	1,197,647.48	598,823.74
Kansas	54	Sedgwick	5.590	Concrete	Apr. 7	375,328.24	73,950.00
	52	Wyandotte and Leavenworth	8.120	do	Apr. 9	377,058.00	121,800.00
	53	Doniphan	6.110	do	Apr. 26	311,025.00	91,650.00
Kentucky	27	Perry	3.140	Asphalt surface	Apr. 2	193,944.58	62,800.00
	28	Barren	25.850	Macadam	Apr. 12	342,601.49	171,300.74
Louisiana	66	Tensas	21.070	Gravel	Apr. 6	331,503.45	167,251.72
	65	Martin	4.950	do	Apr. 9	75,312.52	37,656.26
	41	Jefferson	2.880	Shell	do	30,466.48	15,233.24
	17	Tangipahoa	4.910	Sand-clay	Apr. 12	65,541.08	32,770.54
	56	La Salle	12.980	Gravel	Apr. 21	111,820.83	55,910.41
	53	Madison	10.490	Sand-clay	Apr. 26	134,332.55	67,166.27
	54	St. Bernard	3.220	Macadam	Apr. 30	73,282.22	36,641.11

[1] Withdrawn.

[2] Amounts given are decreases over those in original statements.

PROJECT STATEMENTS APPROVED IN APRIL, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Maine	22	Kennebec	2.870	Bituminous macadam	Apr. 2	$90,893.88	$45,446.94
	23	....do	8.570	....do	....do	268,003.89	134,001.94
	24	Aroostook	3.310	Gravel	Apr. 9	55,656.04	27,828.02
	25	....do	6.510	....do	Apr. 26	112,828.32	56,414.16
Massachusetts	33	Middlesex	3.806	Macadam	Apr. 7	176,572.00	76,120.00
	36	Barnstable	25.456	Sand asphalt	Apr. 26	440,075.90	220,037.95
	34	Worcester	1.359	Concrete	Apr. 24	66,715.00	27,180.00
Michigan	33	Alcona and Alpena	26.976	Gravel	Apr. 2	462,538.98	231,269.49
Minnesota	79	Hubbard	8.810	....do	Apr. 3	48,126.10	24,063.05
	106	Benton	14.980	Concrete	....do	580,773.16	290,386.58
	115	McLeod	9.960	Gravel	....do	52,838.50	26,419.25
	157	Stasca	0.790	Brick, concrete, or asphalt	....do	31,026.20	15,513.10
	89	Le Sever	7.500	....do	....do	275,638.00	137,819.00
	108	Grant	15.370	Gravel	....do	89,860.10	44,930.05
	143	Beltrami	6.270	....do	Apr. 7	34,964.60	17,482.30
	156	....do	9.000	....do	....do	47,960.00	23,980.00
	169	Hubbard	7.460	....do	....do	40,869.40	20,434.70
	133	Waseca	14.260	....do	Apr. 12	111,174.80	55,587.40
	135	Beltrami	3.000	....do	....do	12,320.00	6,160.00
	152	Wadena	7.000	....do	....do	45,155.00	22,577.50
	153	Blue Earth	17.250	....do	....do	97,570.00	48,785.00
	158	Stasca	15.560	....do	....do	100,658.80	50,329.40
Mississippi	55	Panola	33.800	Earth	Apr. 2	213,015.00	100,000.00
Missouri	92	Marion	20.000	Gravel	Apr. 24	249,943.38	124,971.69
	96	Platte	13.700	Earth	Apr. 12	120,385.34	60,192.67
	93	....do	12.060	....do	Apr. 21	231,950.24	115,975.12
	95	Howard	1.000	Chat	....do	11,800.00	5,900.00
	94	Buchanan	0.376	Concrete	Apr. 24	29,899.26	7,520.00
Montana	84	Roosevelt	98.000	Gravel	Apr. 2	279,400.00	139,700.00
	95	Hill	36.000	....do	....do	209,880.00	104,940.00
	85	Fergus	18.000	Earth	Apr. 6	66,000.00	33,000.00
	92	Granite	8.000	....do	Apr. 2	59,939.00	29,969.50
	103	Fergus	39.000	Concrete and gravel	....do	191,400.00	95,700.00
	106	Carbon	12.000	Gravel	Apr. 9	77,932.80	38,966.40
	107	....do	8.800	....do	....do	46,545.77	23,272.88
	66	Blaine	13.000	....do	Apr. 26	74,971.60	37,485.80
	58	Flathead	3.000	Crushed rock	Apr. 24	10,988.56	5,494.28
	97	Broadwater	15.800	....do	Apr. 26	79,125.75	39,562.87
	101	Blaine	11.000	Gravel	....do	47,960.00	23,980.00
	63	Missoula	19.900	....do	Apr. 30	89,281.72	44,640.86
	102	Flathead	4.000	....do	Apr. 26	19,552.50	9,776.25
	105	Park	6.800	....do	Apr. 24	55,306.02	27,653.01
	31	....do	3.600	....do	Mar. 11	21,903.20	10,951.60
	32	....do	3.000	....do	....do	21,100.20	10,550.10
Nebraska	141	Rock and Brown	10.800	Sand clay	Apr. 6	59,899.84	29,949.92
	144	Morrill and Scotts Bluffs	16.400	Gravel	....do	78,936.00	39,468.00
	55	Saline	11.000	Earth	Apr. 9	42,570.00	21,285.00
Nebraska	108	Cherry and Sheridan	59.500	....do	....do	255,849.00	127,924.50
	145	Harlem and Phelps	25.900	....do	Apr. 26	97,977.00	48,988.50
	146	Keith	21.400	Sand clay	....do	102,410.00	51,205.00
Nevada	29	Washoe	10.483	Concrete	Apr. 3	369,194.33	184,597.16
	30	Ormsby	3.490	....do	Apr. 2	118,953.16	59,476.58
	28	Douglas	0.630	....do	Apr. 24	28,013.81	12,600.00
New Hampshire	90	Hillsborough	1.300	Asphalt	Apr. 7	25,000.00	12,500.00
	101	Rockingham	1.536	....do	Apr. 9	35,000.00	17,500.00
	106	Hillsborough	0.379	Gravel	Apr. 7	9,000.00	4,500.00
	100	Belknap	0.800	....do	Apr. 9	10,007.58	5,003.79
	91	Grafton	0.890	....do	Apr. 12	12,000.00	6,000.00
	104	Merrimack	0.820	....do	Apr. 21	10,000.00	5,000.00
	94	Cheshire	0.419	....do	Apr. 26	11,992.03	5,996.01
	97	....do	0.625	Bituminous macadam	....do	20,000.00	10,000.00
	103	Merrimack	0.455	Gravel	....do	10,000.00	5,009.00
	105	....do	1.140	....do	....do	14,097.73	7,048.86
	108	Grafton	1.930	Bituminous macadam	....do	65,000.00	32,500.00
	110	Merrimack	1.330	Asphalt	....do	25,000.00	12,500.00
	96	Hillsborough	0.380	Gravel	Apr. 24	7,590.00	3,750.00
	102	Merrimack	0.910	....do	Apr. 30	10,000.00	5,000.00
	109	Strafford	0.797	....do	....do	15,190.00	7,550.00
	113	Hillsborough	0.420	Bituminous macadam	....do	6,010.29	3,005.14
	114	Strafford	1.630	Gravel	....do	25,000.00	12,500.00
	115	Rockingham	1.210	....do	....do	15,000.00	7,500.00
New Jersey	27	Sussex	7.005	Concrete	Apr. 2	477,327.78	140,100.00
	28	Camden	4.907	....do	....do	226,949.54	98,140.00
	29	Atlantic	9.356	....do	Apr. 24	492,250.00	187,120.00
	39	Mercer, Burlington	2.457	....do	....do	166,722.82	49,140.00
	21	Morris	[16].592	....do	Apr. 5	[1] 597,917.23	[1] 156,840.00
	25	Atlantic and Burlington	[12].253	Gravel	....do	[1] 88,044.65	[1] 44,022.32
New Mexico	44	Hidalgo	8.000	....do	Apr. 24	53,807.60	26,903.80
New York	48	Wayne	1.600	Concrete	Apr. 3	64,000.00	32,000.00
	49	....do	1.100	....do	....do	44,000.00	22,000.00
	57	Genesee	2.100	....do	....do	84,000.00	42,000.00
	44	....do	2.800	....do	....do	112,000.00	56,000.00
	53	Jefferson	3.300	....do	....do	132,000.00	66,000.00
	60	Herkimer	1.200	....do	....do	48,000.00	24,000.00
	50	Hamilton	9.200	Bituminous macadam	....do	331,200.00	165,600.00
	32	Fulton and Saratoga	11.600	Concrete	Apr. 9	464,000.00	232,000.00
	51	Rockland	3.500	....do	Apr. 12	140,000.00	70,000.00
	52	Dutchess	3.900	....do	Apr. 9	156,000.00	78,000.00
	54	Madison	6.200	....do	....do	248,000.00	124,000.00
	55	Franklin	8.100	....do	....do	324,000.00	162,000.00
	56	Dutchess	5.000	....do	....do	200,000.00	100,000.00
	58	Cheming	2.800	....do	....do	112,000.00	56,000.00
	59	Onondaga	4.000	....do	....do	160,000.00	80,000.00
	61	Livingston	5.300	....do	Apr. 12	212,000.00	106,000.00
	15	Otsego	[1] 5.070	Macadam	Apr. 10	[1] 101,400.00	[1] 50,700.00
	23	Schoharie	2.760	Concrete	....do	94,100.00	47,050.00
North Dakota	75	Mountrail	16.000	Earth	Apr. 6	57,705.00	28,875.00
	86	Ward	12.000	Gravel	Apr. 3	67,320.00	33,660.00
	62	McLean	10.000	Earth	....do	31,460.00	15,730.00
	85	Ward	14.000	Gravel	Apr. 12	78,540.00	39,270.00
	83	....do	10.000	....do	Apr. 30	47,300.00	23,650.00
Ohio	137	Sandusky	6.540	Brick	Apr. 9	395,000.00	106,000.00
Oklahoma	30	Nowata	5.000	Gravel	Apr. 2	41,800.00	20,900.00

[1] Withdrawn.

PROJECT STATEMENTS APPROVED IN APRIL, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Oregon	44	Gilliam	8.880	Gravel	Apr. 6	$63,624.00	$31,812.00
	39	Deschutes	17.500	Crushed rock	Apr. 7	179,057.89	89,528.94
	43	Crook	15.150	Gravel	do	168,301.48	84,150.74
	42	Umatilla	22.000	Gravel and crushed rock	Apr. 21	133,925.00	66,962.50
Pennsylvania	68	York	6.052	Concrete	Apr. 2	286,481.36	121,040.00
	69	do	4.878	do	do	245,996.10	97,560.00
	70	Adams	5.594	do	do	315,639.67	111,880.00
	73	Adams and Franklin	8.364	do	Apr. 9	457,258.49	167,280.00
	72	Adams	8.741	do	do	454,998.17	174,820.00
	75	Erie	6.722	Concrete or bituminous	Apr. 12	398,063.40	134,440.00
	71	Lawrence	5.423	Concrete	do	289,910.70	108,460.00
	78	Monroe	7.094	Concrete and brick	Apr. 24	435,671.40	141,880.00
	76	Mercer	9.168	Concrete	do	484,578.10	183,360.00
South Dakota	23	Jackson and Washabaugh	7.950	Gravel	Apr. 2	[1] 47,752.22	[1] 23,876.11
Tennessee	32	Lauderdale	7.717	Macadam	Apr. 6	268,735.02	134,367.51
	35	Hamilton	10.143	Concrete	do	405,702.29	202,851.14
	43	Shelby	7.429	Bituminous macadam	Apr. 3	172,501.28	86,250.64
	26	Maury	11.872	do	Apr. 24	460,557.24	230,278.62
Texas	93	Cameron	3.106	Concrete	Apr. 3	113,816.20	30,000.00
	132	Parker	31.600	Gravel	do	602,712.00	200,000.00
	143	Denton	8.000	do	do	204,476.20	100,000.00
	149	Orange	10.000	Concrete	Apr. 6	400,070.00	200,000.00
	137	Limestone	28.329	Gravel and crushed rock	Apr. 9	325,205.49	92,600.00
	131	Bexar	16.000	Gravel and bituminous surface	do	179,122.02	81,078.81
	142	Harrison	23.210	Gravel	Apr. 12	378,596.83	189,298.41
	154	Bastrop	2.280	do	do	20,534.56	10,267.28
	162	Potter	22.973	Bituminous	Apr. 26	575,000.00	200,000.00
	155	Gaudalupe	18.500	Gravel	do	149,814.50	74,907.25
	160	Upshur	8.988	do	do	79,100.54	39,550.27
	153	Rains	22.300	do	Apr. 21	265,738.26	100,000.00
	156	Titus	5.110	do	Apr. 30	39,400.21	19,700.10
	159	Shelby	31.900	do	do	565,523.66	141,380.91
	54	Walker	5.300	Gravel or macadam	Apr. 14	[2] 14,341.80	[2] 7,170.00
Utah	24	Carbon	11.030	Concrete	Apr. 12	606,725.53	222,582.42
Vermont	15	Chitteuden	4.034	Macadam surface	Apr. 6	153,258.60	76,629.30
Washington	60	Snohomish	3.090	Concrete	Apr. 2	112,056.34	56,028.17
	58	Mason	1.960	Gravel	Apr. 6	29,499.80	14,749.90
	63	Stevens	4.060	do	Apr. 21	32,743.70	16,371.85
	61	Lewis	1.240	do	Apr. 24	34,215.50	17,107.75
	69	Chelan	1.700	Concrete	do	64,533.26	32,266.63
	62	Yakima	5.760	do	Apr. 26	237,893.31	75,000.00
	51	Pierce	4.270	do	Apr. 6	184,772.72	85,400.00
West Virginia	89	Logan	2.700	do	Apr. 7	107,998.00	53,536.42
	91	Barbour	2.000	Macadam	Apr. 9	55,680.00	27,840.00
	93	Monongalia	2.120	Concrete	do	81,100.00	31,120.00
	92	Brooke	0.960	do	do	24,324.30	10,240.00
Wisconsin	117	Shawano	5.020	Gravel	do	63,000.71	21,700.00
	143	Calumet	4.820	Concrete	Apr. 12	162,000.00	54,000.00
	104	Ozaukee	2.460	do	do	90,092.20	30,000.00
	110	Waukesha	3.040	do	Apr. 16	101,147.15	31,000.00
	131	Adams	4.500	Sand-clay	Apr. 12	45,031.14	16,000.00
	133	Waushara	2.320	do	do	18,436.57	7,000.00
	159	Washington	1.710	Concrete	do	60,394.16	20,750.00
	162	Kenosha	3.010	do	do	123,377.82	43,388.00
	163	Kewaunee	2.970	Gravel	Apr. 15	43,964.45	19,500.00
	165	Vilas	9.510	Sand-clay or gravel	Apr. 30	59,999.96	21,000.00
Wyoming	76	Park	4.964	Selected material	Apr. 2	49,808.00	24,904.00
	62	Sweetwater	16.190	do	do	50,710.00	25,355.00
	67	Johnson	7.360	do	Apr. 9	57,640.00	28,820.00
	77	Fremont		Bridge	do	12,232.00	6,116.00
	64	Carbon	7.424	Crushed rock	do	73,040.00	36,520.00
	66	Campbell	21.400	Selected material	do	159,280.00	79,640.00
	69	Johnson	10.750	do	do	83,710.00	41,855.00
	73	Laramie	9.476	do	do	71,390.00	35,695.00
	78	Fremont	9.133	do	Apr. 12	51,150.00	25,575.00
	87	do	4.116	do	Apr. 24	88,440.00	44,220.00
	22	Lincoln		Bridge	Apr. 12	[1] 115,720.00	[1] 57,860.00

[1] Amounts given are increases over those in original statements. [2] Withdrawn.

PROJECT AGREEMENTS EXECUTED IN APRIL, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	60	Monroe	9.230	Gravel	Mar. 15	$26,734.18	$13,367.09
Arizona	18 C, D	Pima and Cochise	11.060	Local material	Apr. 2	36,172.27	18,086.13
Arkansas	45	Lonoke	6.420	Gravel with asphalt treatment	Apr. 9	84,741.69	21,000.00
	31	Cleveland	8.030	Gravel	Apr. 1	85,880.02	23,000.00
	56	do	4.000	Clay-bound gravel	Apr. 9	19,026.70	8,700.00
	34	Cross	2.550	Gravel and macadam	Apr. 22	26,477.00	13,200.00
Georgia	79	Bibb	6.614	Concrete	Apr. 2	255,448.57	110,855.20
	63	Wilkes	0.616	Bituminous macadam	Apr. 17	16,774.49	8,387.24
	121	Randolph	5.549	Sand-clay	Apr. 10	35,069.93	15,000.00
	61	Wilkes	2.143	Bituminous macadam	do	61,015.98	30,507.99
	62	do	0.568	do	Apr. 17	15,323.69	7,661.84
	12	Thomas		Concrete bridges	Mar. 13	[1] 15,333.78	[1] 7,666.89
	4	Ocomee and Walton		Sand-clay	Apr. 2	[2] 42,247.96	[2] 26,258.70
Idaho	10	Elmore	12.530	Gravel	Apr. 17	96,313.20	48,156.60
	12	do	7.400	Crushed lava rock	do	74,953.06	37,476.53
Illinois	2K-15d	Kankakee	2.114	Concrete	Apr. 15	66,283.36	33,141.68
	8T	Macoupin	2.998	do	do	157,189.58	65,651.95
	9-36	Bond	3.830	do	do	152,712.71	76,356.35
	9-33	Madison	3.743	do	do	153,646.59	76,823.29
	9-34	Bond	3.657	do	do	150,506.66	75,253.33
	9-35	do	4.519	do	do	309,748.16	144,695.54
	6I	Peoria	4.952	do	do	176,399.27	88,199.63
	2-5	Iroquois and Kankakee	8.435	do	do	291,866.05	145,933.02
	2-4	Iroquois	6.503	do	do	165,649.75	82,824.87
	6L	Peoria	1.594	do	do	78,099.05	31,880.00
Indiana	4	Putnam and Hendricks	8.103	do	Apr. 2	373,004.90	162,060.00

[1] Modified agreements. Second revision. Increase. [2] Modified agreements. Amounts given are increases over those in the original agreements.

PROJECT AGREEMENTS EXECUTED IN APRIL, 1920—Continued.

State	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Kansas	13A, B	Leavenworth	5.073	Concrete	Apr. 2	$243,278.48	$76,095.00
	34A	Bourbon	5.910	Bituminous macadam	Apr. 1	151,153.20	75,576.60
	3D	Barton	5.265	Brick and concrete	Apr. 12	175,657.98	78,975.00
	5A, B	Bourbon	8.694	Bituminous macadam	Apr. 16	218,139.31	109,069.65
	29D, G	Dickinson	3.960	Brick	Apr. 14	270,426.10	59,400.00
	38	Greenwood	5.858	Concrete	do	261,225.21	87,870.00
	18	Allen	0.920	do	Apr. 28	42,211.21	13,800.00
	33A	Bourbon	3.980	Bituminous macadam	Apr. 16	108,094.33	54,047.16
	13C	Leavenworth	4.416	Concrete	Apr. 28	201,503.08	66,240.09
Kentucky	18	Jefferson	4.507	do	Apr. 7	193,722.12	95,674.80
	19	Mercer	7.133	Water-bound macadam	do	92,745.22	46,372.61
Michigan	4A	Presque Isle		Gravel	Apr. 2	[1] 5,388.89	[1] 2,780.92
Minnesota	51	Crow Wing	19.290	do	Apr. 6	143,428.18	54,000.00
	87	Yellow Medicine	5.973	do	Apr. 9	37,163.09	17,000.00
	36	Fairbault	24.110	do	Apr. 21	198,283.75	73,000.00
Mississippi	20	Walthall	16.230	do	do	120,278.62	60,000.00
	16	Simpson		do	Apr. 2	[1] 13,541.51	[1] 6,770.66
Nebraska	34A	Garfield	5.940	Sand-clay	Apr. 11	45,467.22	22,733.61
	35A	Douglas	1.905	Earth	do	11,356.56	5,678.28
	71	Harlan and Franklin	27.400	do	Apr. 26	229,528.93	114,764.46
	72A	Cedar	10.448	do	Apr. 11	63,003.43	31,501.72
	98B	Lancaster	11.917	do	do	45,003.39	22,501.69
	115	Platte	2.590	Concrete	do	134,811.76	51,800.00
	27	Saunders and Dodge		Earth and gravel	do	[2] 21,552.72	[2] 10,776.36
New Hampshire	80	Rockingham		Concrete bridge	Apr. 9	[1] 1,047.20	[1] 523.60
	28	Merrimack and Grafton		Gravel	Apr. 14	[1] 1,113.20	[1] 556.60
New Mexico	26	Bernalillo	9.563	Concrete	Apr. 6	313,546.43	156,773.21
New York	17	Wayne	5.020	Reinforced concrete	Apr. 21	198,200.00	99,100.00
	18	do	5.950	do	Apr. 22	238,000.00	119,000.00
	36	Broome	4.350	do	do	174,000.00	87,000.00
North Carolina	67B	Nash	3.810	Topeka on concrete base	Apr. 10	158,393.54	76,200.00
	86A	Mastin and Bertie	3.090	Top soil	do	98,454.67	49,227.33
	91	Surry	10.680	do	do	112,416.31	56,207.65
	92A	do	10.827	do	do	106,022.62	53,011.31
	39	Union	12.890	Bituminous macadam or topsoil	Apr. 9	155,336.69	77,668.34
	36	Durham	4.019	Concrete and topsoil road	Apr. 22	[3] 84,991.72	
North Dakota	25	Ward	0.290	Gravel	Apr. 14	[1] 1,425.05	[1] 712.53
Ohio	76	Belmont	4.454	Water-bound macadam	Apr. 6	106,000.00	40,000.00
Oklahoma	12	Tulsa	48.070	Concrete	Apr. 27	1,270,469.46	600,000.00
	16	Hughes		Bridge	do	160,250.36	80,125.18
South Carolina	37A	Aiken	11.685	Sand-clay and gravel	Apr. 9	71,168.93	35,584.46
Tennessee	17	Overton	13.245	Limestone macadam	Apr. 26	269,741.37	134,870.68
	24	Marion	2.318	Water-bound macadam	Apr. 12	85,856.27	42,928.13
	30	Tipton	5.152	Bituminous macadam	do	148,305.74	74,152.80
Texas	53B	Jefferson	3.990	Asphalt on concrete base	Apr. 22	149,717.78	56,999.97
	96	Fisher	8.720	Gravel	Apr. 26	83,704.11	37,034.08
	105	Wood	11.534	do	do	120,258.64	41,500.00
	103	Milam	9.060	do	Apr. 30	53,785.55	26,892.77
	75	Falls		Gravel and stone	Apr. 22	[1] 21,396.46	[1] 11,856.35
Washington	32	Cawlitz	6.670	Gravel	Apr. 26	265,449.42	132,724.71
West Virginia	65	Logan	1.121	Concrete	Apr. 10	41,561.20	20,780.60
	86	Mingo	3.050	Earth	do	43,794.30	21,600.00
	48	Boone		do	Apr. 21		[1] 6,950.50
Wyoming	43	Platte	6.778	do	Apr. 22	28,066.50	14,033.20
	54	Big Horn	3.683	Selected material	Apr. 9	43,844.28	21,922.14

[1] Modified agreements. Amounts given are increases over those in the original agreement.
[2] Modified agreements. Second revision. Increase.
[3] Modified agreements. Amounts given are decreases from those in the original agreement.

NEBRASKA BUYS GRAVEL PIT.

Under the provisions of the law passed by the 1919 legislature the department of public works may acquire land and equipment for road building purposes. The section of the law dealing with this provision is quoted as follows:

That for the purpose of obtaining road materials to be used in the construction and maintenance of State highways built by or maintained under the supervision of the department of public works, said department is hereby empowered, on behalf of the State, to acquire lands and appurtenances thereto, either by purchase or by condemnation proceedings, in the manner provided by law. Said board may also purchase all necessary equipment and employ the necessary labor to remove such materials from said lands; to prepare such materials for use; and to manufacture such materials into road-making products, and may sell any surplus of such materials or products to any county or counties, or to any municipalities of the State, or to any contractor, at actual cost, for building and maintaining roads, streets, and alleys only, and the funds received therefor shall be, by said department, paid into the State treasury and credited to the State aid road fund. The cost of acquiring said lands and appurtenances, the purchase of equipment, and the use of such equipment as provided for in this section, shall be paid out of the State aid road fund.

In accordance with the provisions of the law quoted above, the department purchased May 1 a gravel pit located northeast of the town of Ashland, on the O. L. D. highway and C. B. & Q. tracks. The pit contains 750,000 cubic yards of gravel, and the site consists of 63.29 acres. The sand available in the pit may well be used for building purposes, as it is of a desirable kind. The 750,000 cubic yards of gravel is the most desirable feature, as the State is contemplating building gravel and concrete roads on many of the road projects.

The pit is located in a very desirable position, as it adjoins the Burlington Railroad, and a spur can be run very easily through the center of the location. Because of this feature, two drag lines can be operated at the same time, and the output nearly doubled, and loaded directly into the cars on track.

Another feature of the location that is of importance, is that it is located on the O. L. D. highway between Omaha and Lincoln. At the present rate of improvement it is estimated that 75 per cent of the total of 69 miles between Omaha and Lincoln will be improved after the 1920 and 1921 highway work has been completed. A large portion of this mileage will be paved, it is anticipated, and perhaps the remainder will be graveled.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
249. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States. 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States, 1914. A Summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
463. Earth, Sand-Clay, and Gravel Roads.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
691. Typical Specifications for Bituminous Road Materials.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and Classification of Rocks for Road Building, Including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
77. Experimental Roads in the Vicinity of Washington, D. C.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918.
Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D– 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D– 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D– 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D– 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D– 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 5, D–12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 10, No. 7, D–13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D–15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D–16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

AGRICULTURAL REFERENCE DEPARTMENT
CLEMSON COLLEGE LIBRARY

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 26 WASHINGTON, D. C. JUNE, 1920

LYMAN LAKE AND HANGING GLACIER, CHELAN NATIONAL FOREST

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Four Years of Road Building under the Federal-Aid Act 3
Thos. H. MacDonald

Federal Road Building in the National Forests of the West 15
L. I. Hewes

Selection and Comparison of Federal-Aid Road Types 29
E. W. James

Federal-Aid Allowances 33

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

FOUR YEARS OF ROAD BUILDING UNDER THE FEDERAL-AID ACT.

By THOS. H. MACDONALD, Chief of Bureau of Public Roads.

PENETRATION MACADAM ROAD, FEDERAL-AID PROJECT NO. 67, BERKELEY COUNTY, WEST VIRGINIA.

ON July 11, 1916, President Wilson signed the measure generally known as the Federal-aid road act, under which the Government has since cooperated with the States in the construction of highways. For nearly a century previous the Government had taken no part whatever in the improvement of the roads of the country. By signing the road measure, therefore, the President gave his approval to a radical departure from existing governmental policy. The new policy did not contemplate the construction of Federal roads as a separate system apart from the systems of State and local roads; on the contrary, it aimed to stimulate the construction of the roads of the country through the agency of State highway departments.

After four years of operation under this plan it is appropriate that we stop for a moment to review the methods which have been adopted by the Government and the States in putting into effect the purposes of the act; and to examine the progress that has been made toward the goal that was set.

OUTSTANDING RESULTS OF FEDERAL AID.

In spite of the delays incident to the prosecution of the greatest of wars; in the face of strikes which have crippled the transportation systems of the country and reduced the output of necessary materials of construction to a degree unprecedented in the history of the Nation, the program of cooperative highway construction, laid down in 1916, has been adhered to and the results which have been obtained thus far stamp the plan as an unqualified success.

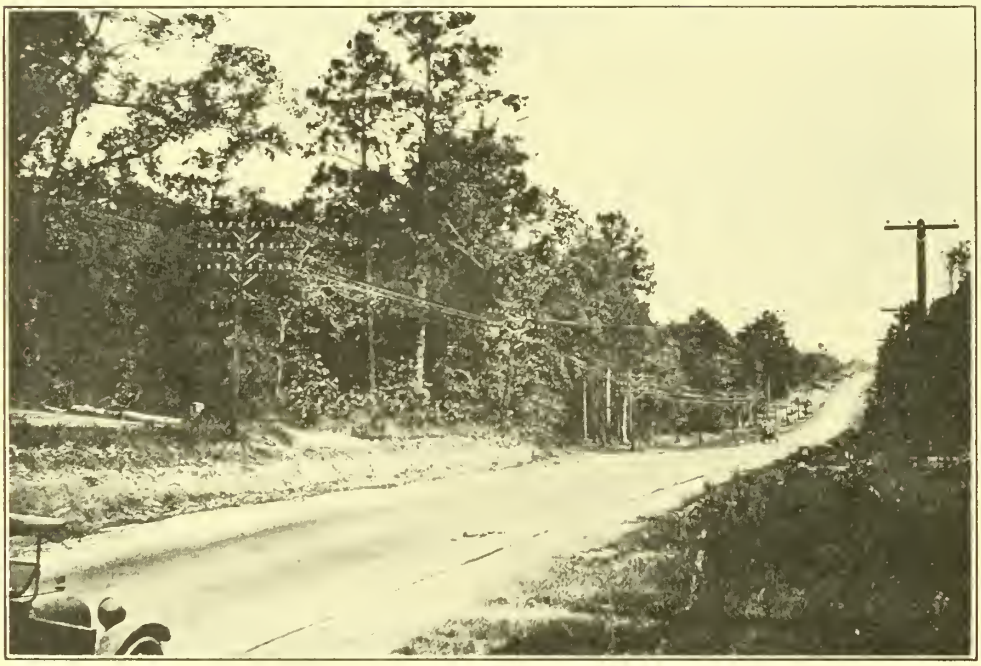
One of the earliest and most far-reaching results, directly attributable to the act, was the creation of adequate State highway departments in 17 States, which previously had either no State department at all or which had departments insufficiently equipped to perform necessary functions. In one year, after the passage of the act, more constructive State highway legislation was placed upon the statute books than had ever before been enacted in the history of the country in a similar period, and a condition was brought about which otherwise would not have been reached in 5 or 10 years. This legislative activity was a direct consequence of the conditions imposed upon the States by the Federal aid act.

The insistence of the Government upon the construction of Federal-aid roads under the supervision of engineers of the State departments has resulted in the placing of more and more of the road work of the country under skilled supervision. In 1915, the year before the Federal-aid act was passed, only 30 per cent of the expenditure for roads and bridges built in the United States was expended under the supervision of State highway departments. This year the State departments will exercise control over fully 80 per cent

of the large sums that will be spent for road construction.

In 1915 the total expenditure for roads and bridges by all the States and local governments was only $267,000,000. This year it is estimated that the funds available for main road construction are approximately $633,000,000. The willingness of the public to appropriate these greatly increased sums is largely traceable to the confidence which has been inspired by the creation and strengthening of the State highway departments, the immediate cause of which was the Federal-aid act.

The manner in which the large sums of Federal money have been apportioned among the States is an accomplishment which has seldom been referred to, but it should be, nevertheless, a source of gratification to all the agencies which have cooperated in the



CONCRETE ROAD IN RAPIDES PARISH, LOUISIANA, PROJECT NO. 13.

work. In all, the sum of $266,750,000 has been divided among 48 States to the entire satisfaction of all interests involved, and without the slightest suggestion of impropriety or the least suspicion of favoritism.

The actual road operations under the act thus far involve the approval of projects the aggregate length of which would span the distance between New York and San Francisco nine times, and the estimated cost of which is greater than that of the Panama Canal. Under construction at the present time there are 15,944 miles of road, equivalent in length to five roads from the Atlantic to the Pacific; and the equivalent of 5,500 miles of road has been completed.

Sixty per cent of the total allotment of Federal funds which has been approved to date will be spent for roads of such durable types as bituminous concrete, Portland cement concrete and vitrified brick; and these roads when they are built will increase by 7,600 miles the total of 14,400 miles of roads of this class which existed in the whole United States the year before the enactment of the Federal aid law.

In their contract with the Government the States have given assurance that every mile of road constructed will be properly maintained; in fact, the requirements of the Federal aid act have been directly responsible for the enactment of laws in a number of States providing specifically for the maintenance of all roads constructed, whether with or without Federal aid.

IMPORTANT PROVISIONS OF THE ACT.

The sum of $75,000,000 which was appropriated by the original act for rural post roads was made available in installments at the rate of $5,000,000 for the fiscal year which ended June 30, 1917, $10,000,000 for the fiscal year 1918, $15,000,000 for 1919, $20,000,000 for 1920, and $25,000,000 for the fiscal year which ends June 30, 1921.

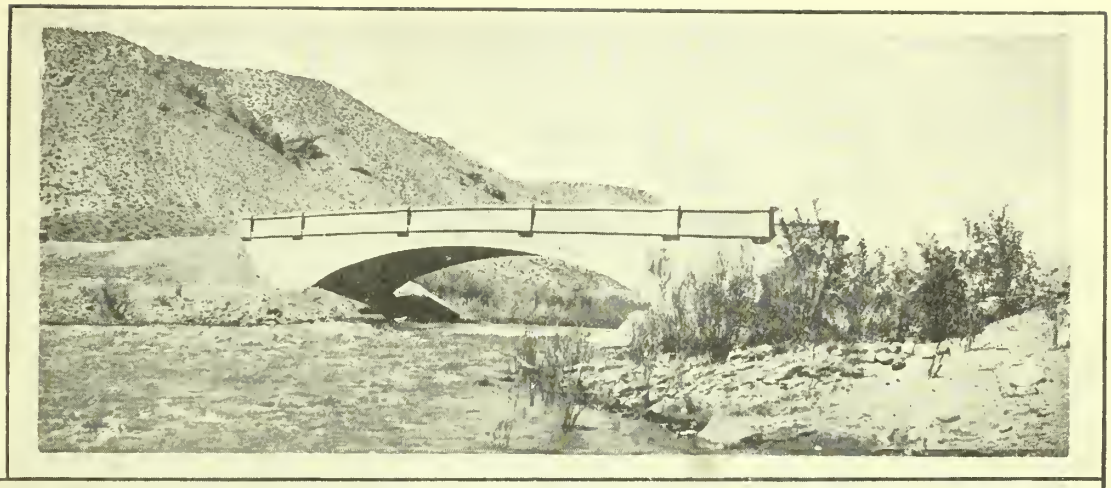
The $10,000,000 for forest roads was made available at the rate of $1,000,000 per year beginning July 1, 1916.

The act provided that a sum not to exceed 3 per cent of the post-road appropriation may be used by the Secretary of Agriculture for administering its provisions.

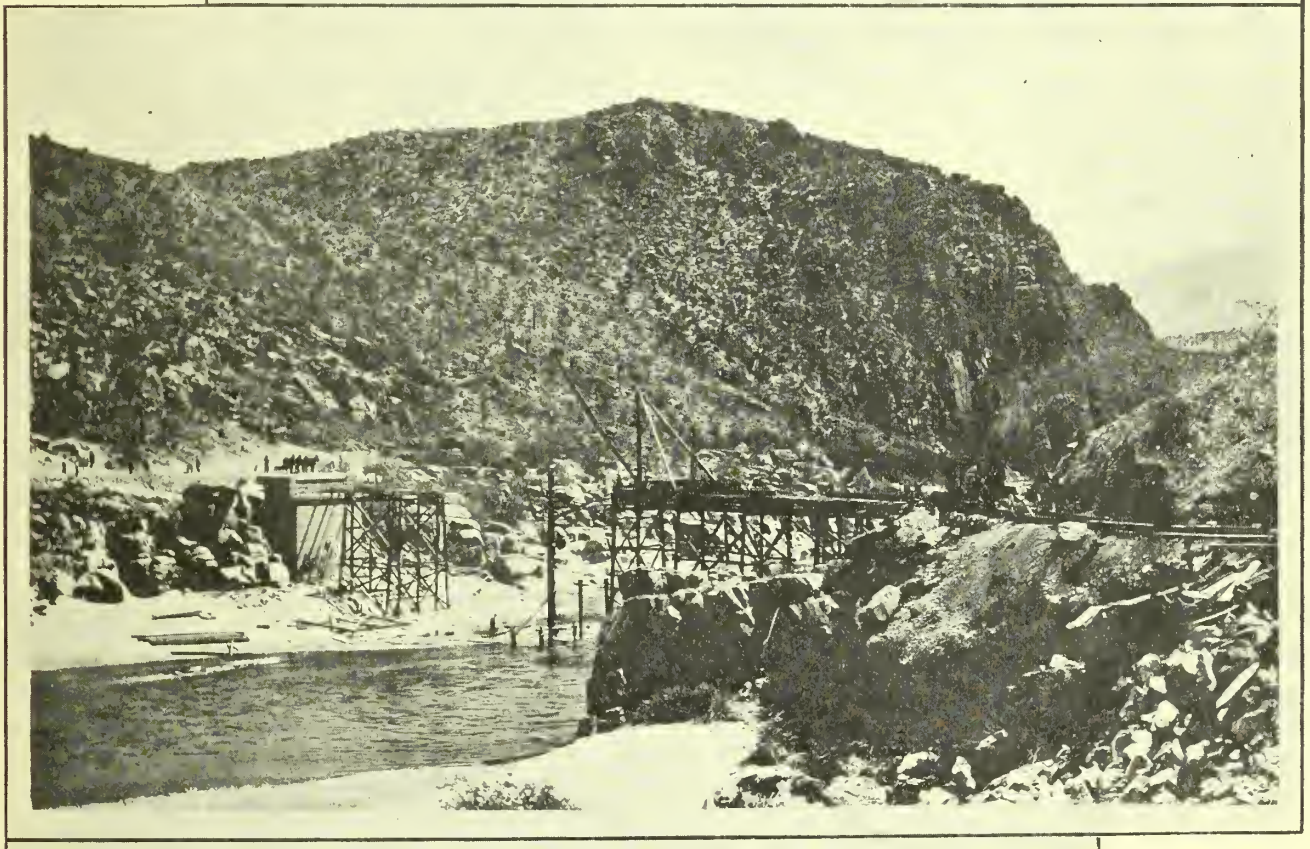
The apportionment of the post-road appropriations of the States, after deducting the administrative fund, is based upon area, population, and mileage of rural delivery and star routes in each State, each of these factors having a weight of one-third.

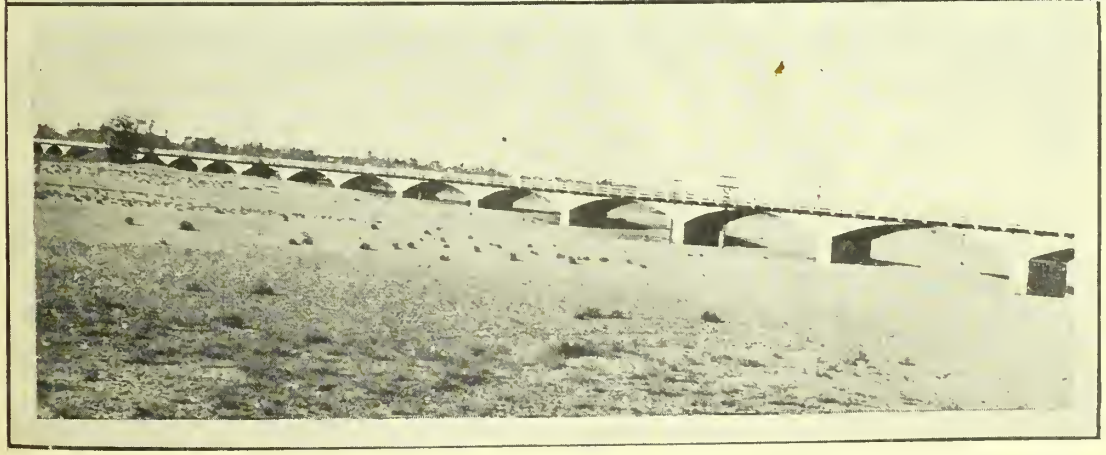
Federal funds may be expended only for construction, must not exceed 50 per cent of the value of the roads, and in the original act it was provided that the expenditure of Government funds could be, in no case, in excess of $10,000 per mile exclusive of bridges of more than 20 feet clear span. This provision was amended by a subsequent act, and the amount of Federal funds which could be expended was increased to $20,000 per mile.

The act laid down three requirements with which the States were asked to comply before they could receive allotments of Federal aid; first, that the State legislatures should assent to the provisions of the act, or that the governors of those States in which the legislative bodies were not in session should assent pending



THE BULKHEAD OF A BRIDGE OVER THE WEST WALKER RIVER, NEVADA, ON FEDERAL-AID PROJECT NO. 8 B.





VIEW OF EAST SIDE OF CAUSEWAY OVER MAIN OVERFLOW CHANNEL OF SACRAMENTO RIVER, ON CALIFORNIA PROJECT NO. 42. THE CAUSEWAY CONSISTS OF 30 65-FOOT SPANS.

BRIDGE BUILDING ON FEDERAL-AID PROJECTS IN THE WEST. THE CENTER VIEW IS OF SALT RIVER BRIDGE, ON PROJECT NO. 14, ARIZONA, IN COURSE OF ERECTION.

the convening of the legislatures; second, that each State should have a State highway department, and that these departments should have direct supervision over the construction on which Federal funds were to be expended; and third, that the Federal aid should be met by an appropriation of at least an equal amount of State funds. A number of States in turn require certain conditions to be met by their counties, such as the raising of county funds, the establishment of guarantees as to maintenance, and the taking of certain administrative steps contemplated by State highway laws. But the Secretary of Agriculture deals only with the State highway department, and thus the State in meeting Federal requirements, acts for the counties whenever their interests are involved.

ARIZONA PROJECT NO. 16. THIS ROAD WILL REDUCE THE DISTANCE BETWEEN PHOENIX AND GLOBE BY 30 MILES, AND FURNISH COMMUNICATION FOR MANY MINING CENTERS.

An immense amount of preliminary work was necessary before the terms of the act itself could be put into operation. First, the Secretary of Agriculture was required to apportion the Federal funds for the first fiscal year to all the States, and in doing this it was necessary that he ascertain from the Postmaster General the "corrected" mileage of rural delivery and star routes, as these formed one of the factors of apportionment.

The act next required the establishment of rules and regulations, and, in their preparation, it was necessary that the views of the several State highway departments should be given careful consideration. The act was approved July 11, 1916, and 10 days later, July 21, 1916, the certificate of apportionment was issued. The rules and regulations, prepared after a conference with the State highway officials, were issued September 1, 1916. After that it was necessary to ascertain which of the States were equipped with highway departments within the meaning of the act, and to await the assent of the State legislatures to the provisions of the act, or of the governors pending the convening of the legislatures in those States in which the legislative bodies were not in session, so that it was 1917 before actual construction work could be undertaken under the terms of the act.

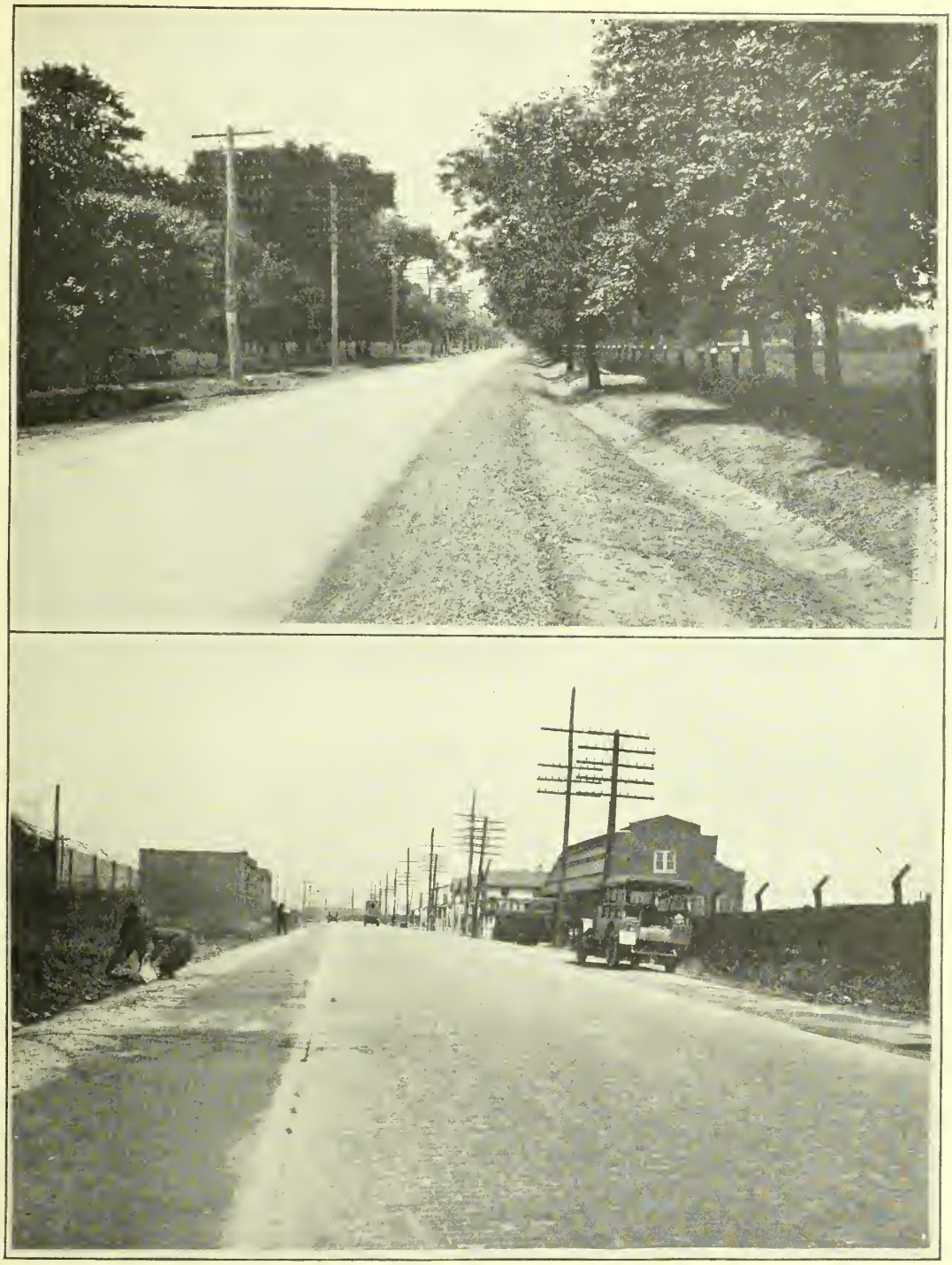
At the outset the States were required to settle upon a definite system of roads in the construction of which they would ask for Federal aid. These systems were selected and maps of them were submitted to the Bureau of Public Roads. Except in about 5 per cent of the projects where the desirability of revisions in these systems has since been made evident, the apportionments of aid to the States have been expended upon parts of these systems. These systems involve about 214,000 miles of road, or only about 8 per cent of the total of 2½ million miles of road in the United States.

This work had hardly begun when war with Germany was declared on April 6, 1917, and from that time until the signing of the armistice, 19 months later, the energies of the Nation were directed to the winning of the war. Other interests were subordinated to the one great aim; and Federal aid road construction was curtailed, wherever possible, to release vitally necessary men and materials for the more important purposes of war.

PROVISIONS OF THE 1919 LAW.

Something over three months after the signing of the armistice, on February 28, 1919, the President, in signing the Post Office appropriation bill for 1920 approved amendments to the original Federal aid act, which provided that the term "rural post roads" as used in that act was to be construed to mean "any public road a major portion of which is now used, or can be used, or forms a connecting link, not to exceed 10 miles in length of any road or roads now or hereafter used for the transportation of the United States mails * * *," and further increased the limitation of $10,000 per mile to $20,000 per mile, as stated above.

Prior to the enactment of these amendments no project could be approved by the Secretary of Agriculture unless it could be ascertained either that the



TOP, NEW JERSEY PROJECT NO. 14, CONCRETE ROAD FROM KINGSTON TO NEW BRUNSWICK. BOTTOM, DELAWARE PROJECT NO. 1, WILMINGTON TO PENNSYLVANIA LINE.

mails were actually carried on the road comprised in the project, or that they would be carried on it within a reasonable time after its completion. A large number of projects had been submitted by the States which the Secretary of Agriculture could not approve because of doubt as to their post road status. The passage of the amendment with its broad construction of the term "rural post roads" permitted the Secretary to approve these projects, all of which were for important roads, and cleared the way for a far more logical selection of the roads to be improved.

The amendment also made it possible for the States to devise more compact State systems on which to apply Federal aid without the danger of having parts of the system ineligible under the original definition of post roads.

The Post Office appropriation bill of February 28, 1919, carried an additional appropriation of $200,000,000 for the construction of Federal aid roads and $9,000,000 additional for the construction and maintenance of roads and trails in the national forests. The new Federal aid appropriation was made available in installments of $50,000,000 immediately, $75,000,000 for the fiscal year ending June 30, 1920, and $75,000,000 for the fiscal year ending June 30, 1921, while the forest road appropriation was made available in three equal installments of $3,000,000 each, available immediately, and for the fiscal years 1920 and 1921, respectively.

The total appropriations made by the acts of 1916 and 1919 for Federal aid and forest roads, and the installments of each by years and the allotments of Federal funds to the several States, by years, are shown in the following table:

APPROPRIATIONS FOR FEDERAL AID AND FOREST ROAD CONSTRUCTION.

Fiscal year.	By act of July 11, 1916.		By act of Feb. 28, 1919.		Total Federal aid.	Total forest.
	Federal aid.	Forest.	Federal aid.	Forest.		
1917	$5,000,000	$1,000,000			$5,000,000	$1,000,000
1918	10,000,000	1,000,000			10,000,000	1,000,000
1919	15,000,000	1,000,000	$50,000,000	$3,000,000	65,000,000	4,000,000
1920	20,000,000	1,000,000	75,000,000	3,000,000	95,000,000	4,000,000
1921	25,000,000	1,000,000	75,000,000	3,000,000	100,000,000	4,000,000
1922		1,000,000				1,000,000
1923		1,000,000				1,000,000
1924		1,000,000				1,000,000
1925		1,000,000				1,000,000
1926		1,000,000				1,000,000
Total	75,000,000	10,000,000	200,000,000	9,000,000	275,000,000	19,000,000

ALLOTMENTS OF FEDERAL AID TO STATES BY YEARS.

State.	Under act of 1916—fiscal year.					Under act of 1919—fiscal year.		
	1917	1918	1919	1920	1921	1919	1920	1921
Alabama	$104,148.90	$208,297.80	$313,456.47	$420,105.64	$526,220.88	$1,050,264.10	$1,575,396.16	$1,578,662.63
Arizona	68,513.52	137,027.04	205,540.58	274,017.43	343,411.04	586,043.58	1,027,565.38	1,030,233.12
Arkansas	82,689.10	165,378.20	250,018.47	336,091.81	421,294.52	840,229.52	1,260,344.28	1,263,883.57
California	151,063.92	302,127.84	456,167.23	609,699.32	763,668.88	1,524,248.30	2,286,372.45	2,291,006.63
Colorado	83,690.14	167,380.28	257,278.92	347,028.36	438,939.79	867,570.91	1,301,356.36	1,316,819.38
Connecticut	31,090.44	62,180.88	92,216.45	122,825.86	153,337.36	307,064.66	460,596.98	460,012.07
Delaware	8,184.37	16,368.74	24,411.99	32,553.78	40,668.70	81,384.46	122,076.68	122,006.11
Florida	55,976.27	111,952.54	170,723.88	229,518.88	286,861.98	573,797.20	860,695.79	860,585.94
Georgia	134,329.48	268,658.96	403,909.45	538,417.90	674,287.74	1,346,044.75	2,019,067.12	2,022,863.22
Idaho	60,463.50	120,927.00	182,471.55	244,203.71	306,512.48	610,509.27	915,763.90	919,537.45
Illinois	220,926.23	441,852.46	658,323.48	874,220.26	1,091,266.98	2,185,550.65	3,278,325.98	3,273,800.93
Indiana	135,747.62	271,495.24	406,230.18	539,967.76	671,763.32	1,349,919.42	2,024,879.12	2,015,289.95
Iowa	146,175.60	292,351.20	434,653.61	577,218.48	720,332.18	1,443,046.20	2,164,569.31	2,160,996.56
Kansas	143,207.40	286,414.80	429,131.88	574,525.57	717,811.16	1,436,313.92	2,154,470.88	2,153,433.46
Kentucky	97,471.91	194,943.82	292,984.62	390,746.07	487,938.86	976,865.18	1,465,297.76	1,463,816.57
Louisiana	67,474.66	134,919.32	203,755.29	272,291.61	340,557.78	680,729.02	1,021,093.54	1,021,673.35
Maine	48,541.50	96,903.00	144,807.42	192,492.62	240,057.54	481,231.55	721,847.32	720,172.62
Maryland	44,047.22	88,094.44	130,871.43	173,894.81	216,749.65	434,737.02	652,105.54	650,248.96
Massachusetts	73,850.95	147,701.90	221,261.85	294,753.32	368,197.21	736,883.30	1,105,324.94	1,104,591.62
Michigan	145,783.72	291,567.44	435,356.37	578,885.52	722,916.99	1,447,213.81	2,170,820.72	2,168,750.98
Minnesota	142,394.06	284,788.12	425,865.40	568,309.81	710,522.33	1,420,774.52	2,131,161.78	2,131,567.00
Mississippi	88,905.84	177,811.68	268,751.60	359,795.31	451,889.29	899,488.28	1,349,232.41	1,355,667.88
Missouri	169,720.41	339,440.82	508,603.98	678,125.64	846,974.90	1,695,314.10	2,542,971.16	2,540,924.70
Montana	98,287.19	196,574.38	298,520.89	399,786.86	501,747.53	999,467.14	1,499,200.72	1,505,242.60
Nebraska	106,770.81	213,541.62	319,445.25	426,656.83	533,435.50	1,066,642.07	1,599,963.10	1,600,306.48
Nevada	64,398.30	128,796.60	193,229.82	257,173.38	319,086.11	642,933.46	964,400.19	957,258.32
New Hampshire	20,996.62	41,993.24	62,610.11	83,124,15	103,709.73	207,810.38	311,715.56	311,129.20
New Jersey	59,212.68	118,425.36	177,357.22	237,620.32	296,889.11	594,050.80	891,076.19	890,667.34
New Mexico	78,737.81	157,475.62	238,634.55	319,514.31	399,616.96	798,785.79	1,198,178.68	1,198,850.89
New York	250,720.27	501,440.54	749,674.20	995,182.56	1,242,973.28	2,487,956.40	3,731,934.59	3,728,919.83
North Carolina	114,381.92	228,763.84	342,556.47	455,990.99	569,763.45	1,139,977.46	1,709,966.20	1,709,290.35
North Dakota	76,143.06	152,286.12	229,585.91	307,344.11	384,056.95	768,360.28	1,152,540.42	1,152,170.85
Ohio	186,905.42	373,810.84	558,043.42	741,784.99	926,561.70	1,854,462.49	2,781,693.74	2,779,685.11
Oklahoma	115,139.00	230,278.00	346,489.34	461,222.20	575,619.58	1,153,055.49	1,729,583.24	1,726,858.75
Oregon	78,687.37	157,374.74	236,332.74	314,983.64	394,038.01	787,459.10	1,181,188.64	1,182,114.02
Pennsylvania	230,644.17	461,288.34	690,145.78	918,430.34	1,147,986.51	2,296,075.84	3,444,113.77	3,443,959.54
Rhode Island	11,665.71	23,331.42	34,972.38	46,612.38	58,314.22	116,530.95	174,796.42	174,942.65
South Carolina	71,807.64	143,615.28	215,014.08	286,918.82	359,004.76	717,297.06	1,075,945.58	1,077,014.28
South Dakota	80,946.02	161,892.04	243,175.61	324,288.27	403,944.86	810,720.66	1,216,081.00	1,211,834.58
Tennessee	114,153.48	228,306.96	340,663.51	452,841.40	565,478.48	1,132,103.49	1,698,155.24	1,696,435.42
Texas	291,927.81	583,855.62	876,986.70	1,170,487.75	1,465,399.62	2,926,219.37	4,389,329.06	4,396,198.84
Utah	56,950.15	113,900.30	170,763.17	227,036.84	282,393.91	567,592.10	851,388.16	847,181.75
Vermont	22,844.47	45,688.94	68,128.92	90,395.08	112,519.27	225,987.69	338,981.54	337,557.82
Virginia	99,660.71	199,321.42	298,120.77	396,821.18	494,418.46	992,052.95	1,488,079.42	1,483,255.37
Washington	71,884.28	143,768.56	216,530.19	288,946.90	361,156.95	722,367.24	1,083,550.87	1,083,470.84
West Virginia	53,270.46	106,540.92	159,713.89	212,803.64	265,038.19	532,009.11	798,013.66	795,114.58
Wisconsin	128,361.07	256,722.14	382,707.20	509,178.61	636,236.34	1,272,946.52	1,909,419.78	1,908,709.01
Wyoming	61,196.82	122,393.64	183,805.78	245,164.98	308,428.96	612,912.44	919,368.67	925,286.88
Total	4,850,000.00	9,700,000.00	14,550,000.00	19,400,000.00	24,250,000.00	48,500,000.00	72,750,000.00	72,750,000.00

ORGANIZATION AND PROCEDURE.

Under the law the Secretary of Agriculture is charged with the administration of the provisions of the Federal aid act. He in turn has delegated the duty of caring for the details of administration to the Bureau of Public Roads. This Bureau was at the time of the passage of the act, and is now, in closer touch with the highway situation and requirements of the country as a whole than any other agency in the United States. Under any other agency Federal operation would have been delayed to permit of the acquisition of necessary preliminary data, which the Bureau of Public Roads had at hand, ready to utilize without delay.

The organization under the Chief of the Bureau of Public Roads which cares for the details of the administration of Federal aid funds consists of a headquarters force headed by the chief engineer in the Washington office, and 13 district engineers in charge of the work in 13 groups of States. The districts vary in size. One embraces only one State, California; others include four or five States; the largest one includes eight States. The district engineers are assisted by a number of engineers who have supervision over sections of the district work. Where the work is sufficiently heavy to warrant it, one or more resident engineers have been placed in a State. In other districts, men are assigned by the district

PENNSYLVANIA FEDERAL-AID PROJECT NO. 29. LEFT, BITUMINOUS MACADAM ROAD, MILFORD TO MATAMORAS, PIKE COUNTY. RIGHT, BITUMINOUS CONCRETE ROAD.

engineer to cover special States, but do not have headquarters in those States. These men are authorized to approve slight changes in plans which become necessary as the work progresses, such as changes in the size of waterways, location of culverts, slight changes in grade and alignment, and even more important changes, providing they do not involve the Government in additional expense. By thus making it possible to effect minor engineering adjustments on the ground, a great deal of time is saved, which would be lost if it were necessary to refer such matters to Washington.

The Federal aid act requires that projects for Federal aid be initiated by the States. As the first step, a statement is forwarded to the district engineer in authority, announcing, in effect, that the State proposes to build a piece of road of a certain type and length in a certain location. This statement is known as the project statement, and it is always accompanied by an approximate estimate of the cost of the proposed construction. The project statement is examined by the district engineer with the purpose of determining whether the project complies with the Federal aid road act. If, in his opinion, it does he forwards the statement to the Washington office with his recommendation. It is there examined by the chief engineer and his assistants, and, if the chief engineer concurs in the recommendation of the district engineer, the project is placed before the Secretary of Agriculture by the chief of the bureau, with the recommendation of the bureau, for his approval.

PROJECTS RAPIDLY CONSIDERED.

Until the Secretary has signified that the United States will cooperate, no further action is taken by the State. If the Secretary approves, the State is so notified, and it then proceeds to prepare detailed plans, specifications and estimates for the work. According to recent reports over half of the projects handled are passed by the district offices in an average of five days. Greater delay at this stage is generally due to the necessity for careful investigation to determine whether the road proposed is of sufficient importance to warrant the expenditure of Federal money upon it. When these doubtful points are cleared up the prompt passage of the project to approval by the Secretary is practically assured, as is shown by the fact that 90 per cent of all projects received at Washington are passed by the bureau in an average of four days.

After the plans and specifications have been prepared by the States they are submitted to the district

engineers, together with a revised estimate of cost based on the carefully computed quantities of work to be done. A representative of the district engineer, either the Federal engineer resident in the State or one especially assigned, makes an inspection of the site of the proposed work, and on this inspection the district engineer bases his recommendation for approval or disapproval of the plans. Very frequently the Federal engineer does not wait until the plans are completed, but goes over the road to be built with the State engineer, pencil profile in hand, and he is often able in this way to suggest changes in the plans as contemplated which facilitate their approval when they are completed.

As soon as the plans, specifications, and estimates are recommended for approval by the district engineer the State may advertise for bids and let the contract. There may be minor adjustments and changes to be made in the plans before they are finally approved by the Secretary, but generally speaking the States do not wait for all these matters to be cleared up before they initiate work on the project. The records of the Bureau of Public Roads show that the plans, specifications, and estimates for over half of the projects are passed through the district offices in an average of five and one-half days and about 90 per cent receive the approval of the chief engineer in three and one-half days. Delays at this stage of the project are generally due to differences of judgment which are serious enough to be given special consideration.

After the plans, specifications, and estimates have been approved, the cooperation of the Government is practically assured. The signing of the formal project agreement follows in due course, but it is not necessary that the work be delayed pending this formality. The authority granted by the Secretary to proceed with construction before the formal completion of the agreement has practically removed all cause for criticism of the Government on the ground of delay.

To cover the cost of administrative work of the Government, an amount not to exceed 3 per cent of the total appropriation for Federal aid is reserved. As the total cost of Federal aid projects is more than twice the amount of the Federal aid apportionment to them, the administrative allowance is really less than 1½ per cent of the total cost of the roads constructed.

ACTUAL ROAD CONSTRUCTION.

Up to June 30, 1920, 2,985 projects involving a total of 29,319.3 miles of road had been approved by the Secretary of Agriculture. The preliminary estimate of the cost of these projects is $384,916,819.53, of which $163,841,503.93 will be approved as Federal aid. On the same date 2,116 projects representing approximately 15,944 miles had either been completed or were under construction. The estimated total cost of these projects in various stages of construction and completed is $200,000,000, and as they average about 34 per cent completed, the value of the work which had been done up to June 30 is approximately $68,000,000. The projects which have been placed under construction since the signing of the armistice involve an expenditure of approximately $181,150,000; those which had been undertaken prior to that time involved only $18,850,000. This means that the actual construction which has been undertaken in the 19 months since the cessation of hostilities is nearly ten times as great as that which had been initiated in the two years and a quarter prior to that time.

It is interesting to observe that the total cost of Federal aid work approved by the Secretary in the 19 months subsequent to the signing of the armistice and prior to July 1, which is approximately $330,000,000, exceeds by $63,000,000 the cost of all road and bridge work done by States and counties in the United States in the year 1915; and that it is only $40,000,000 less than the total cost of the work done by Americans on the Panama Canal. The performance of this Government in the construction of the canal has been regarded, the world over, as a record-breaking achievement in respect to the dispatch with which it was carried out. The cost of that work was $373,000,000 and it required 10 years to complete, the rate of expenditure being therefore $37,000,000 per year. That record has been equaled by the Federal Government and the States in the construction of Federal-aid roads since the armistice, for in the time since that date—about 19 months—construction work costing $60,000,000 has been completed, a rate of expenditure of $37,000,000 per year. This rate has been attained in the face of the worst economic conditions which have been experienced in a century, and in spite of railroad strikes, inadequate transportation facilities, and shortage of construction materials and labor.

CHARACTER OF FEDERAL-AID ROADS.

The law requires that any construction undertaken under the cooperative plan shall be "substantial in character." Further than this the determination as to the type of the selected roads is left to the joint decision of the Secretary of Agriculture and the State highway departments.

In interpreting the word "substantial" the Secretary has taken cognizance of the fact that an improvement which is substantial for one density and kind of traffic may not be substantial for another. It has been recognized that the types of roads which it is desirable to construct in New York, Massachusetts, and Pennsylvania are not suitable or necessary for Nevada, Idaho, and the Dakotas.

The fact that the former groups of States have a density of population of from 170 to 400 people per

CONCRETE BRIDGE, PROJECT NO. 95, OHIO COUNTY, WEST VIRGINIA. VIEW FROM END OF PROJECT NO. 46 AND BEGINNING OF NO. 95, LOOKING EAST. THE TROLLEY TRACK IS TO BE LOWERED TO THE GRADE OF THE ROAD.

square mile, while the latter have from less than 10 to less than 1, is sufficient to indicate that the road type requirements of the two groups are far from identical. Such a conclusion is reinforced by an examination of the number of automobiles and motor trucks owned and operated in the several States in relation to the mileage of their roads. Thus in the States of Alabama, Arkansas, Nevada, South Dakota, and Oklahoma the number of motor vehicles owned and operated is only 1 per mile of road, while in California there are 8 per mile, in Massachusetts there are 13 per mile, in New Jersey 13, and in Rhode Island 21. Recognizing these facts, the decision as to the type of road which the Secretary will approve for a given locality has been based in every case upon the traffic which is using the existing road and which it is estimated will use the improved road.

The natural conditions obtaining in the several sections of this large country are so diverse that an attempt to fit a uniform type of road of uniform construction as to depth of surfacing or width of right of way would result in overimprovement in one section and perhaps in underimprovement in another. By this it is not meant to infer that no effort has been made to effect standardization of practices and methods where standardization is practicable. On the contrary, as early as April 28, 1917, standards governing the form and arrangement of plans, specifications, and estimates for Federal-aid projects were adopted and issued, and all States have since been working in absolute conformity to these standards in submitting Federal-aid projects. Indeed, they are making use of these standards in connection with work in which the Federal Government does not participate.

This is a case in point to illustrate that the Federal-aid plan has resulted in a standardization of procedure. It has done more: the influence of the Bureau of Public Roads has operated powerfully in the standardization of the details of specification and methods used in the construction of the various types of road the country over. The Bureau has been a clearing house for the collection and dissemination of the best ideas of all the State forces, and through its contact with all the States it has been able to raise the standard of construction in many States by directing attention to improved methods in use in other States. But in deciding upon the adequacy of plans proposed for particular Federal-aid projects the determination as to the type of road which will be constructed, as well as to the location, width, and other matters, is based upon an ascertainment of the facts in the particular case, which is as complete as it may be made. Such decisions must be mutually acceptable to the State highway departments, which look to the interests of the States, and to the Secretary of Agriculture, who acts for the Government. The result is that the Secretary has approved roads of all types and widths, from graded earth roads to concrete, brick, or bituminous concrete, narrow as well as wide; but the essential point is that in each case the decision has

been based upon the best engineering judgment of the Federal Government and the several State highway departments, which between them employ the most highly capable highway engineers in the country.

TYPES OF ROADS APPROVED.

Up to June 30 the total cost of all projects approved by the Secretary was $384,916,819.53. For these projects Federal aid to the amount of $163,841,503.93 has been approved, the apportionment to the various types of road being as shown in the following table:

Proportions of Federal aid approved for various types of surface.

	Per cent.		Per cent.
Earth	8	Low types	26
Sand-clay	3		
Gravel	15		
Waterbound macadam	2	Intermediate types	9
Waterbound macadam, mat-top	1		
Bituminous macadam	5		
Miscellaneous intermediate types	1		
Bituminous concrete	6	High types	60
Concrete	41		
Brick	6		
Miscellaneous high types	7		
Miscellaneous types	5		5

If the various types be divided into three classes, according to their relative wearing qualities under heavy traffic, it will be found that only 26 per cent of the Federal aid approved has been allotted to such roads as earth, sand-clay, gravel, and others which may be regarded as low types. About 9 per cent of the Federal money will be spent for such intermediate types as waterbound and bituminous macadam, and 60 per cent of all the Federal aid approved will go for such high types of construction as bituminous concrete, Portland cement concrete, and brick.

The classification of the mileage of roads approved is somewhat different from the apportionment of the funds. Such a classification is shown in the following table:

Classification of mileage approved—by types.

	Per cent.		Per cent.
Earth	25	Low types	66
Sand-clay	11		
Gravel	30		
Waterbound macadam	4	Intermediate types	9
Waterbound macadam, mat-top	2		
Bituminous macadam	3		
Bituminous concrete	4	High types	23
Concrete	17		
Brick	2		
Miscellaneous			2

It will be noted that, in mileage, the low-type roads preponderate, though the amount of Federal aid allotted to their construction is only about one-quarter of the funds alloted for all types. The mileage of roads of intermediate type is only 9 per cent of the total mileage approved, and 23 per cent of the whole mileage is to be improved with the highest classes of construction.

A large part of the mileage of low-type road which has been approved is in projects in sections of the country where the pioneering work required to open up new territory yet remains to be done. Earth, sand-clay, and gravel surfaces have also been approved in many instances for projects which it is intended at a later date to surface with a more durable material. Whatever money is expended upon such projects for grading and drainage, which represent the major work involved in them, is money well spent for permanent improvement. The slight loss which will be sustained from the depreciation of the surface is far less than the loss which would be sustained as a result of the failure of an expensive surface laid on a new fill.

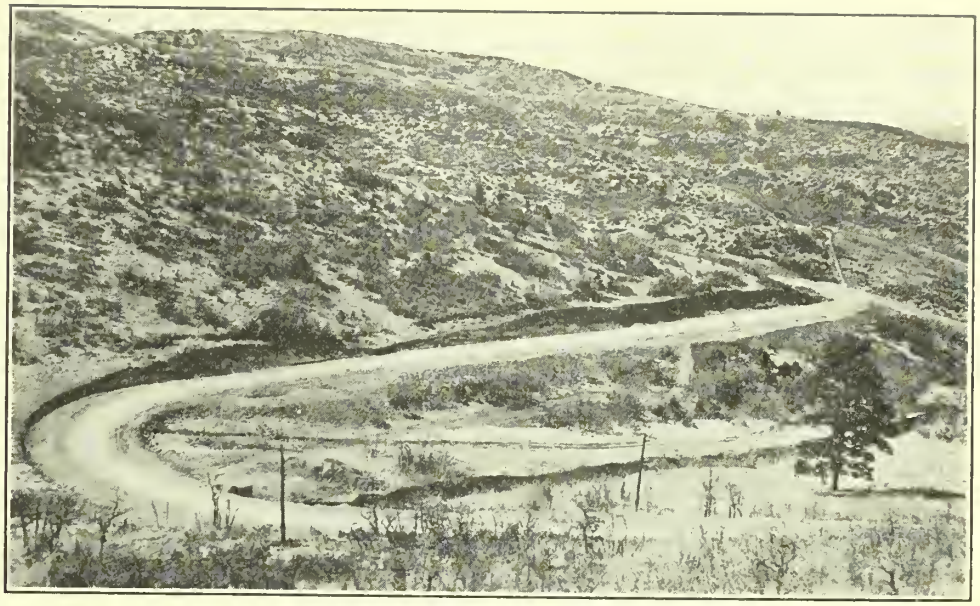
MAINTENANCE OF FEDERAL-AID ROADS.

The Federal-aid act specifically forbids the use of Federal money for maintenance of the roads constructed with Federal aid. The States are expected to maintain the roads constructed; and to enforce proper attention to this important matter, it is provided that future allotments of aid may be withheld from any State which fails to keep its Federal-aid roads in repair. So far it has not been necessary to invoke this provision of the law, and it is unlikely that any State will, in the future, so far neglect its own interest in the roads constructed as to permit the dissipation of its investment in the roads by failure to keep them in repair. The Bureau of Public Roads, however, is making periodic inspections of the roads which have been completed, and will continue to do so, and the States will be expected to comply fully with the terms of their contract with the Government.

FEDERAL SYSTEM OF HIGHWAYS.

In the prosecution of this great work the Federal Government and the several States have acted in the closest cooperation. The dual interest of the Federal and State Governments in the result of the work has been recognized throughout. The roads already constructed and any which may be constructed hereafter will certainly be of greater importance to the States than to the Government at Washington or to the United States as a whole, since 90 per cent of the traffic which will use them will be distinctly local in character. Yet the Federal Government also has an interest in the betterment of the avenues along which this local traffic may flow. A large part of it is the traffic from farms to shipping points and nearby cities and towns; and any improvement which will expedite this traffic will go far to ease the existing critical situation in respect to the supply of agricultural products. This we must regard as most important in these days of high prices of the necessities of life and reduced production of the fruits of the

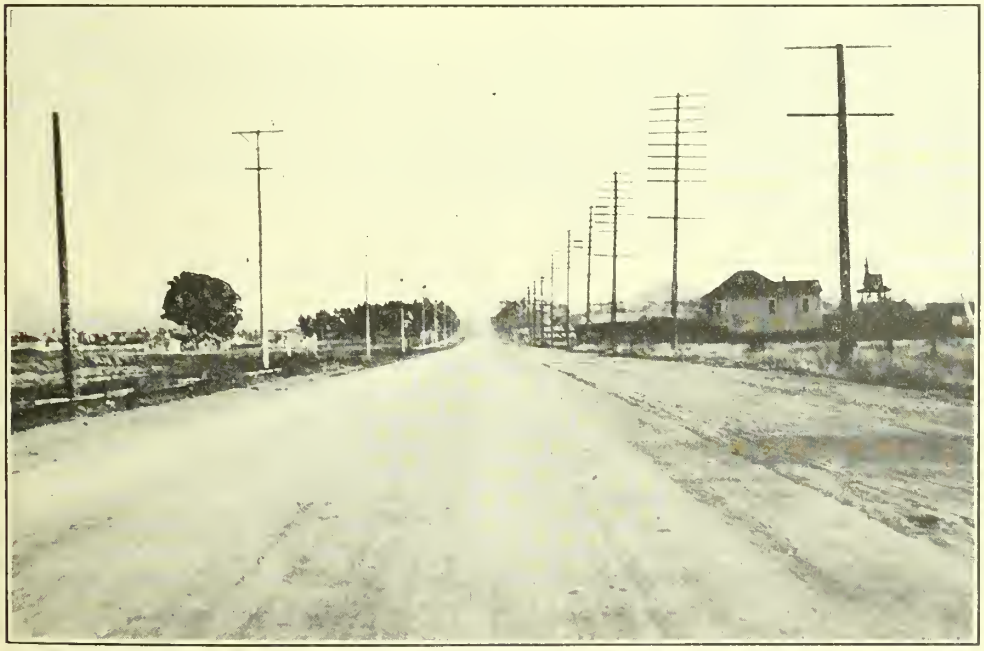
soil. Whatever works will help in the betterment of the conditions of rural life, the promotion of educational and social opportunities of our rural communities, and the development of the inherent attractions of country life, will increase our agricultural population, and consequently our production of the vitally necessary raw materials.



COLORADO PROJECT NO. 2, WHICH CONNECTS TRINIDAD AND RATON PASS ON THE NEW MEXICO LINE.

The Federal Government, of course, has a direct interest in the development of interstate roads to accommodate that 10 per cent of highway traffic which flows across State lines. Previously this traffic has consisted largely of automobiles driven by tourists in the pursuit of pleasure, and the need for roads to accommodate it has been subordinate to the need for the local roads which actually promote the substantial well-being of the country at large; but lately, with the development of the motor truck, the interstate traffic has taken on a somewhat commercial aspect, and the importance of providing for it has increased. However this traffic can be taken care of by suitable connection of the local roads which are the first necessity—not roads to isolated farms, or country lanes for community travel, but roads radiating from the important country shipping centers which will take up and bring to the major transport lines of the railways the crops of the farmer here, there, and everywhere, which in the aggregate make up America's production.

The same policy may be followed with respect to the military roads which the lessons of recent years have shown to be vitally necessary. There is no support for the assumption that long transcontinental roads will be needed for military defense, a transcontinental road which merely crosses the continent is of little military value. What is needed is a series of roads connecting all important depots, mobilization, and industrial centers, which, as thus connected, may give us a transcontinental route eventually; but the transcontinental feature is of secondary importance. In the main these essential military roads coincide with the roads required for the development of industry and agriculture, though in special cases roads will undoubtedly be required to connect points of strategic importance, which would not otherwise be required.



CALIFORNIA PROJECT NO. 3, A 20-FOOT ROAD WITH 1½ TOPEKA TOP ON A 5-INCH 1:3:6 CONCRETE BASE. UNDER TRAFFIC SINCE 1916.

To assure that all these various uses will be adequately provided for, the Chief of the Bureau of Public Roads has called into consultation the several agencies interested in the development of roads for the several purposes, among them, the War Department, and the several State highway departments. The General Staff of the Army and

the Chief of Engineers already have taken up with the department commanders the question of the roads which are of importance from a military standpoint; an advisory committee of State highway officials is cooperating with the Department of Agriculture to select the most important peace-time roads; and, in conference with these agencies, a systematic program of highway development is being worked out for the whole country, upon the basis of which questions of priority in the construction of roads will hereafter be settled.

ASPHALT FILLER IN GRANITE BLOCK WORK.

A typical granite block pavement has just been completed on a section of Battery Place in lower Manhattan, New York. In 1906 this thoroughfare was paved with wood block, but under a series of repairs the pavement was gradually replaced by granite block. This type of pavement was found necessary because of the weighty wagon and automobile freight traffic on Battery Place between Broadway and the North River piers.

In 1918 the work of putting granite block entirely over Battery Place was completed with the exception of a part of the thoroughfare which had been occupied by a large Red Cross storage shed. In May of this year it was decided to raze this shed and to tear up the old wood block on which it was built. Granite block with asphalt filler was the type selected by the street department to conform with the rest of Battery Place.

The 6-inch concrete base upon which the old wood block had been laid was in fairly good shape. With a little filling in of pot holes and leveling off it furnished a satisfactory support for the new granite block. Over this base was spread a cushion of cement and sand which provided an even bed for the granite blocks. The pavers then proceeded with the laying of the blocks, great care being taken to see that they were firmly set in the cushion of sand, to prevent the crushing of unevenly laid blocks. After tamping the pavement was ready for the application of the asphalt filler.

The asphalt filler was heated in a specially designed kettle constructed after specifications furnished by the contractor. The kettle has a capacity of 300 gallons; is able to cover 500 square yards a day, and is built in such a way that maximum benefit is derived from the heat. In case of necessity the filler could be prepared for application in three hours.

The filler in this particular job was applied in the form of a mastic. Equal quantities of asphalt and sand, heated to approximately the same temperature, were mixed thoroughly immediately before being applied. In order to apply them effectively both asphalt and sand were heated to from 350 to 400 degrees Fahrenheit. After a homogeneous mixture had been formed, it was poured directly over the surface of the blocks and forced into the interstices with a hot-iron squeegee.

In this case only one application of the filler was made, but it is often advisable to make two applications. The filler settles in cooling and sometimes leaves the edges of the block unprotected and at the mercy of heavy traffic. As a final step in the construction, sand was spread over the pavement to absorb the surplus asphalt left on the surface. The consolidation of this surplus asphalt and the sand forms a protective mat which greatly reduces the noise of traffic and tends to lengthen the life of the pavment.

A pavement of this type may be open to traffic immediately upon completion.

IOWA ROADS MARKED.

Iowa counties have very largely decided to put up signs along the primary road system. The week of July 12 has been selected as road-marking week. Iowa's road number system is similar to that in use in several Middle Western States—Wisconsin, Ohio, Minnesota, Illinois, Michigan, and Nebraska. In this system an important main-traveled road between important transportation centers is given a designating number, which is painted on telegraph, telephone, or specially erected poles at every intersection, turn, crossroad between these centers, and also at times at points between crossroads. A traveler has simply to follow the route number leading to his destination.

So far as possible numbers on important interstate routes through Iowa have been given numbers corresponding to the number of the same road in adjoining States. When Iowa started numbering her roads it was found that the Jefferson Highway was No. 1 in Minnesota, and that number was assigned to the highway through Iowa. The River to River road in Illinois was No. 7, and it became No. 7 in Iowa. The Blue Grass trail is No. 8 in both Illinois and Iowa.

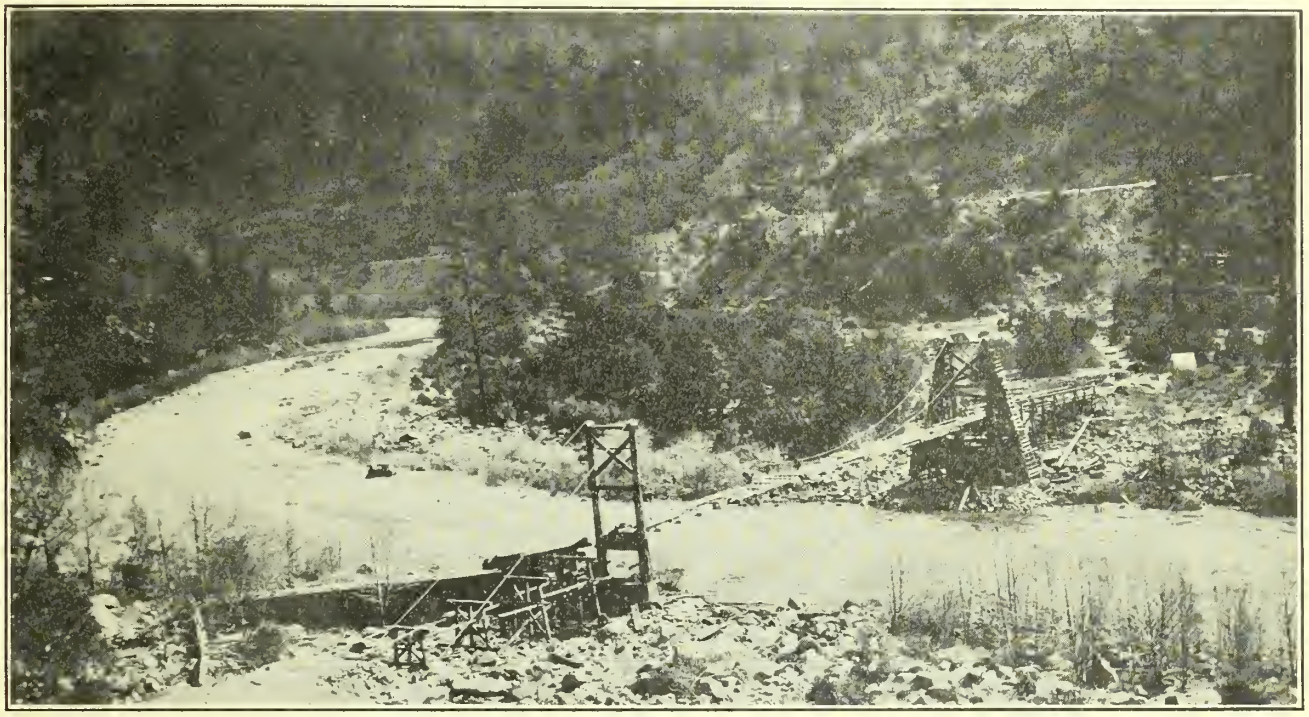
MAINE EXPENDITURES.

Maine in 1919 expended $344,879.58 on State highways, $1,113,998.67 on State-aid highways, and $340,885.74 for bridges, a total of $1,799,763.99 for road construction. For maintenance, $344,879.58 was spent on State highways and $339,091.88 on State-aid highways, a total of $673,971.46.

In the maintenance work 478 patrolmen were employed, 668.60 miles of State highways and 843.72 of improved and 2,772.52 of unimproved State-aid highways were looked after, a total of 4,284.52 miles maintained. In addition, 74.12 miles of State-aid roads were maintained under special arrangements by towns.

FEDERAL ROAD BUILDING IN THE NATIONAL FORESTS OF THE WEST.

By L. I. HEWES, General Inspector, Bureau of Public Roads.



WORKMAN'S BRIDGE ACROSS FEATHER RIVER, PLUMAS NATIONAL FOREST, SHOWING BULKHEAD WHICH PROTECTS NORTH APPROACH DURING HIGH WATER.

WEST of the one hundred and third meridian the people of the United States possess a forest of 154,000,000 acres. This forest lies between the Pacific Ocean and the eastern boundary of Montana, Wyoming, Colorado, and New Mexico. Its definite Federal administration was established by Congress in 1905, and it was subdivided into 6 forest districts and 151 separate national forests.

Within these national forests lie 15,000 miles of State and county highways. The improvement of these roads and the development of additional subsidiary administration and fire protection roads constitutes the national-forest roads project.

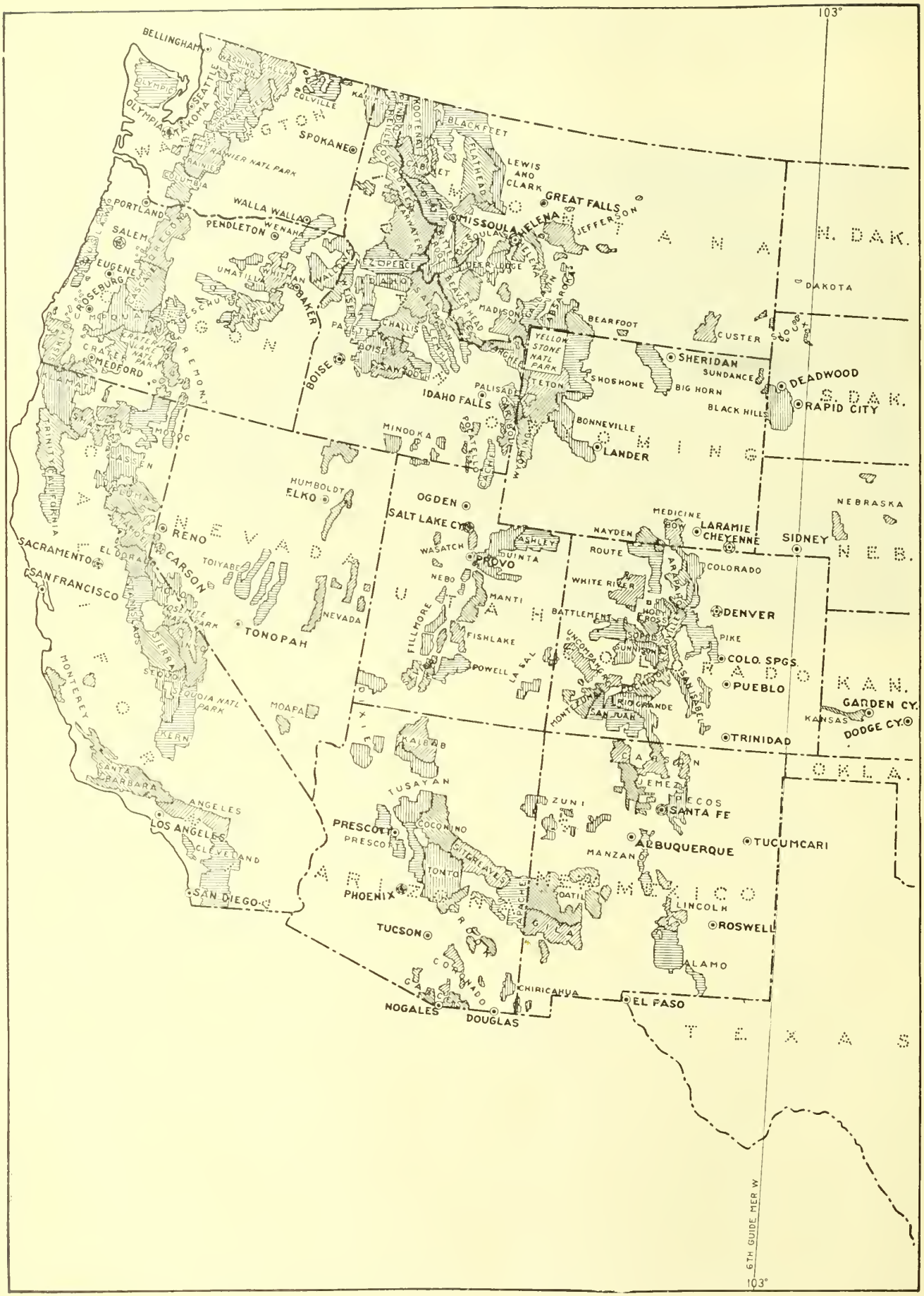
The work of surveying and constructing these highways was begun in 1914. Funds were then very limited and the magnitude of the task was scarcely realized, but the program of survey and construction has now become one of the most extensive in the country. It is directed, cooperatively, by the Forest Service and the Bureau of Public Roads of the Department of Agriculture. The Forest Service classifies the roads within the national forests, sets up a working plan from year to year of the order of improvement of various projects, and enters into agreement with the States and counties to finance the projects. From this point the Bureau of Public Roads takes charge and handles the work of survey and construction.

FINANCING FOREST ROADS.

Federal financing of the national-forest road program has been provided for mainly in three ways. First, in point of time, by the 10 per cent national-forest fund which is made up of 10 per cent of the revenues of the national forests and is applicable to roads and trails within the forests of the State in which the fund originates. This fund in the past eight years has amounted to $2,322,225. It may be used by the Secretary of Agriculture with or without local cooperation. Prior to 1917 most of this money was expended for the construction by the Forest Service of roads of minor standard but vital to the safety and administration of the forests.

Second, the Federal aid road act of 1916 appropriated $1,000,000 annually for 10 years for the construction of the roads and trails within or partly within the national forests with equitable cooperation by the local authorities. This fund has already amounted to $5,000,000.

Third, the emergency appropriation in the amendment to the post-office act of 1919 provided $3,000,000 annually for three years for the construction of roads and trails by the Secretary of Agriculture. The last $3,000,000 becomes available in July, 1920. Roughly speaking, then, there had been made available up to January 1 of the current year approximately



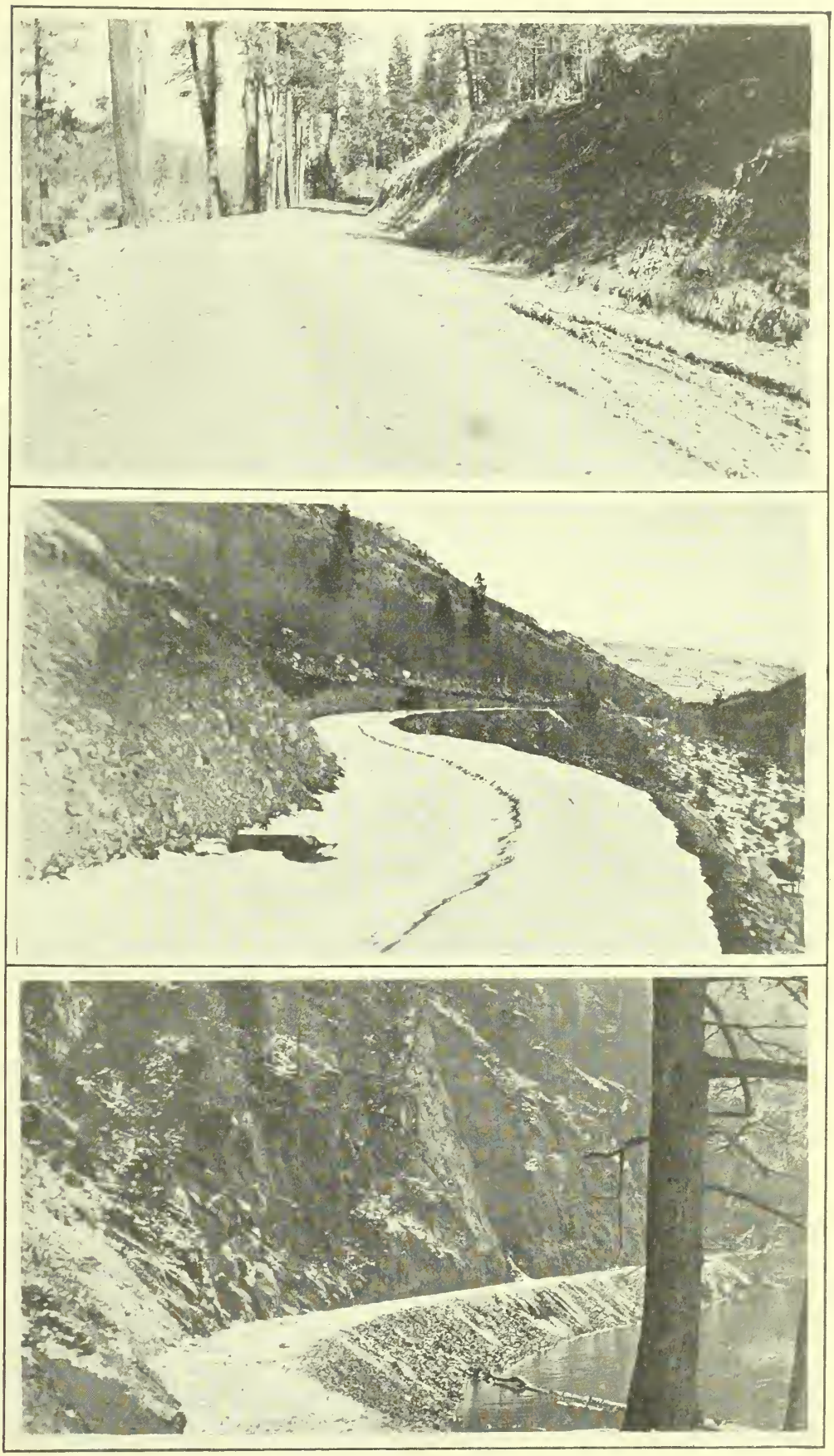
SHADED PORTIONS OF MAP SHOW LOCATIONS OF NATIONAL FORESTS IN THE WEST.

$12,300,000 of Federal funds for the construction of national forest roads. There is at present a total of $6,513,347 worth of construction in progress supervised by the Bureau of Public Roads, and since the passage of the Federal-aid road act 30 projects costing $2,018,703 had been completed. These are major projects only. The construction of minor roads and trails is done entirely by the Forest Service.

AREA AND LOCATION OF THE FORESTS.

The geography of this great forest-road program is indicated by the map of the 11 States on page 16. These States total in area 1,179,095 square miles, which slightly exceeds the combined area of 15 countries of western continental Europe. Over this third of our country are distributed national forests north and south through 17½ degrees of latitude and east and west from the plains to the Pacific. The net forest area is 208,467 square miles, which is over 20,000 square miles greater than all the New England and North Atlantic States.

Looking closer, the map will show that the shaded forest areas coincide with the great mountain ranges. West of Denver are massed the eastern outposts of the Rocky Mountains. Here are forest roads at an elevation of nearly 10,000 feet. From Canada along the Statelines of Montana and Idaho, across the Yellowstone National Park and southward over the flat summit of Sherman



TOP, A GRADED FOREST ROAD IN OCHOCO CANYON, OCHOCO NATIONAL FOREST. CENTER, NEW SNOW ON THE MONARCH PASS ROAD, WHICH CROSSES THE CONTINENTAL DIVIDE IN COLORADO AT A HEIGHT OF 10,000 FEET. BOTTOM, FOREST ROAD ALONG LAKE CRESCENT, OLYMPIC NATIONAL FOREST, WASHINGTON.

Hill extends the Continental Divide through the center of continuous forests. Down into Utah east of Ogden along the beautiful Wasatch Range the forests continue and then beyond the Grand Canyon at the Kaibab Forest to the Tonto Forest of Arizona, in which lies the Roosevelt Dam, and finally through the Apache Forest to the Mexican line. West of the divide in Oregon and Nevada are detached forest areas stretching southwesterly along secondary ranges. In the north the forests of the Blue Mountains form the southern rim of the Columbia River drainage basin and finally reaching across Oregon they join the Cascade Range at Crater Lake. The splendid Cascade Mountains themselves are clearly marked by areas of forests straight from the Canadian boundary across the States of Washington and Oregon and into California. Here the Sierras continue the forest zone southward past Mount Lassen and the Yosemite and Sequoia Parks to the Mojave Desert. All the western peaks are in this area—Baker, Rainier, St. Helens, Hood, and Shasta.

Beginning again in the north at Puget Sound, the great Olympic Forest occupies most of the Olympic Peninsula and other isolated forest areas follow the Coast Range through Oregon southward across the rugged canyon of the Klamath River. In Southern California near the coast are continuous narrow forests of surprising interest, topping for 500 miles the ranges back of Santa Barbara, Los Angeles, and San Diego.

In the Territory of Alaska are the Tongass and Chugach Forests stretching from the coast inland to the mountain tops. They occupy 20,000,000 acres and have 15,000 miles of coast line.

The rocky structure of these western mountain ranges, coupled with the isolation of the projects, the dense forest cover and the snow in the passes make the construction of roads through the national forests possibly the most interesting and probably the most difficult road building in the United States.

ROADS WITHIN THE FORESTS.

During 1919 the Forest Service made a comprehensive investigation of the total mileage of existing county and State roads lying within the boundaries of the forests. The following table shows the result of this study:

State.	State roads.	County roads.	Cost of grading and drainage of State roads, at $15,000 per mile.	Cost of grading and drainage of county roads, at $7,500 per mile.
	Miles.	*Miles.*		
Idaho	153	402	$2,295,000	$3,015,000
Nevada	44	159	660,000	1,192,500
Utah	228	201	3,420,000	1,507,500
Wyoming	77	26	1,155,000	195,000
Montana	65	1,675	975,000	12,561,500
New Mexico	437	43	6,555,000	322,500
Arizona	300	306	4,500,000	2,295,000
Colorado	997	100	14,955,000	750,000
South Dakota	90	170	1,350,000	1,275,000
California	[1] 45 563	3,685	8,445,000	27,637,500
Oregon	[1] 65 345	[1] 220 1,444	5,175,000	10,730,000
Washington	[1] 27 222	[1] 95	3,330,000	.....
Alaska	[1] 30 140	945	2,100,000	7,087,500
Total	[1] 167 3,661	[1] 315 9,156	54,915,000	68,570,000

[1] Already constructed.

If only the roads of greatest duty are surfaced, the improvement of an adequate system of roads to serve as connecting links of State highway systems and as main county laterals and for fire protection, administration, and the development of the forests, will cost over $150,000,000.

WHY FOREST ROAD WORK IMPORTANT.

The importance of this forest road work may best be realized by a study of some of the salient geographic and topographic features of the forest areas. First, because the national forests lie along the mountain summits they contain roads which must cross the mountain passes on all the trunk highways from the Great Plains to the Pacific and from the north to the south. Except to the westerner and the traveler, the the idea of altitude may not carry great significance. But the effect of altitude may be realized when it is stated that from the Canadian boundary to Helena, Mont., there has never yet been built a road crossing the Rocky Mountains. Automobilists who visit Glacier National Park can not drive from Glacier to Bolton, 30 miles away, until the road partly within the Blackfeet Forest along the southern boundary of the park is completed. There is no road in the State of Washington that can be traveled the entire year across the Cascade Mountains between the Inland-Empire and Puget Sound and western Washington populations. The same is true in Oregon. The only all-the-year passable road from the Columbia basin to the coast is down the gorge of the Columbia River; and at the point where the Cascade Range would cross the river a national forest road has just been constructed on the north bank from Stevenson to White Salmon. There are now in process of construction in the 11 Western States more than 20 projects, all of which run over mountain passes at elevations of from 3,000 to 10,000 feet. These particular roads involve some of the most difficult pieces of construction in the entire western road program, and many are connecting links in State highways. The McKenzie Pass Road across the Cascade Mountains between Eugene and Bend in Oregon runs for 3 miles on a mountain top over a fresh lava flow on which not a single plant grows.

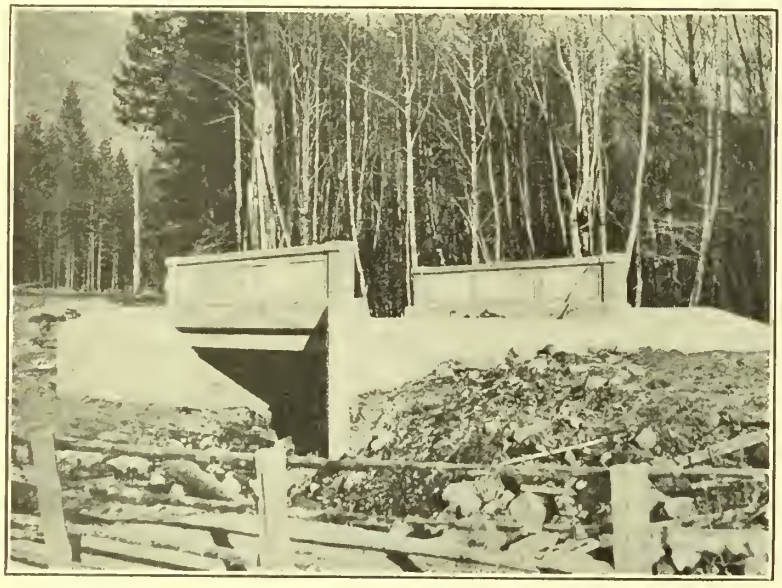
Second, every national park in the western one-third of the continent is practically surrounded by national forests, and motorists can not reach the roads already constructed in the national parks unless the roads through the forests leading to the parks are first constructed.

Glacier National Park in Montana is bordered by the Blackfeet National Forest; the Yellowstone is completely surrounded by six forests, except for a narrow strip along the railroad branch from Livingston. Mount Rainier is completely surrounded; Crater Lake can be approached only through the National forest, although a narrow strip of patented land exists on the southeast; Yosemite is completely surrounded, except for the road to El Porto; and Sequoia lies in the heart of the Sequoia Forest.

COPYRIGHT BY FRED H. KISER, PORTLAND, OREG.

MATCHLESS CRATER LAKE, IN CRATER LAKE NATIONAL FOREST. A FOREST ROAD NOW UNDER CONSTRUCTION WILL REACH THIS LAKE.

Third, in addition to the national parks within the great national forests there lie many natural beauty spots as yet very little known to the public and to which access may be had only by National-forest roads. Such, for example, is the wonderfully beautiful Lake Crescent in the Olympic National Forest. Here, within 9 miles of the Pacific, at an elevation of nearly 500 feet, lies a lake 11 miles long, surrounded by virgin forests, which affords possibly the most splendid trout fishing in the country. Knowing fishermen journey from the ends of the earth to visit this lake in the month of April to catch the extraordinary "Beardslee" and "Crescenti" trout, yet the new forest road which is now under construction as a part of the Olympic Highway will, for the first time, make it accessible to motor traffic from Port Angeles. This road project is in a country where primeval conditions have so long existed that the road blasting has driven the deer to new grounds. In Washington is beautiful Lake Chelan, almost completely surrounded by the Chelan National Forest. The Oregon and Cascade Forests stretch southward from the Columbia River along the mountain summits through a region of lakes and mountain peaks of wonderful beauty. Here lies Clear Lake at the headwaters of the McKenzie River, and world famed Crater Lake far southward, and between them are a dozen snow-capped peaks, such as Jefferson and The Sisters. These lakes have some of the best fishing in America and are inaccessible except to packers and campers. Similar conditions apply to northwestern Montana and central Idaho and to many parts of Colorado and the Southwest; to the forests back of Los Angeles and to the exceptionally interesting California coast country; particularly to the Klamath River in the north, flowing for 60 miles through a forest canyon where the placer diggings of '49 are still visible and at intervals still worked.

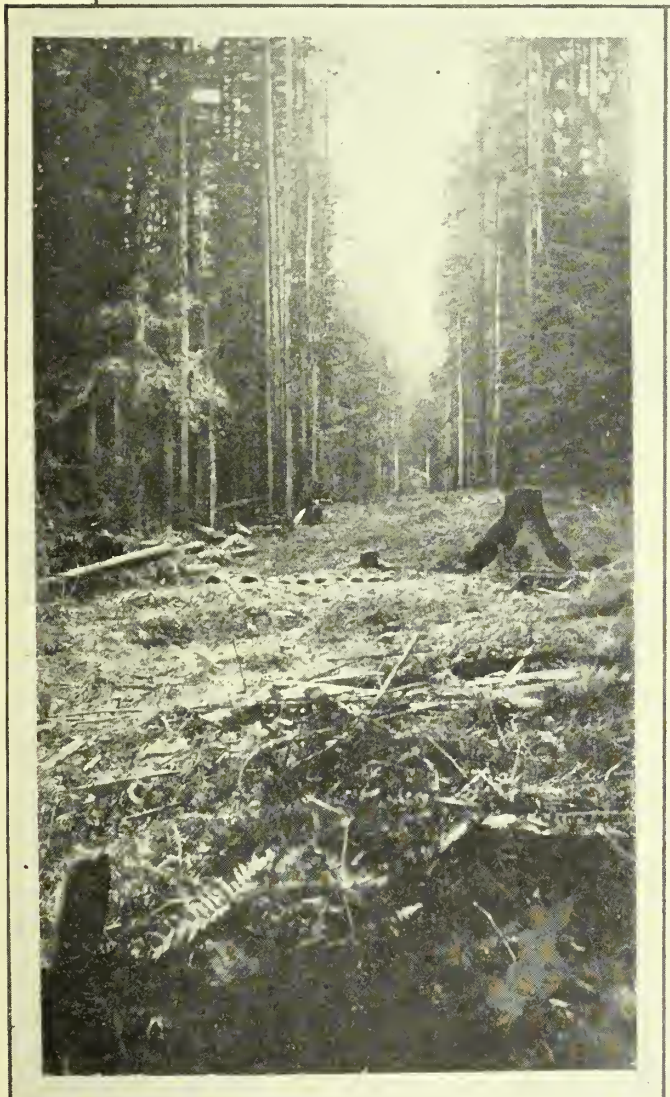


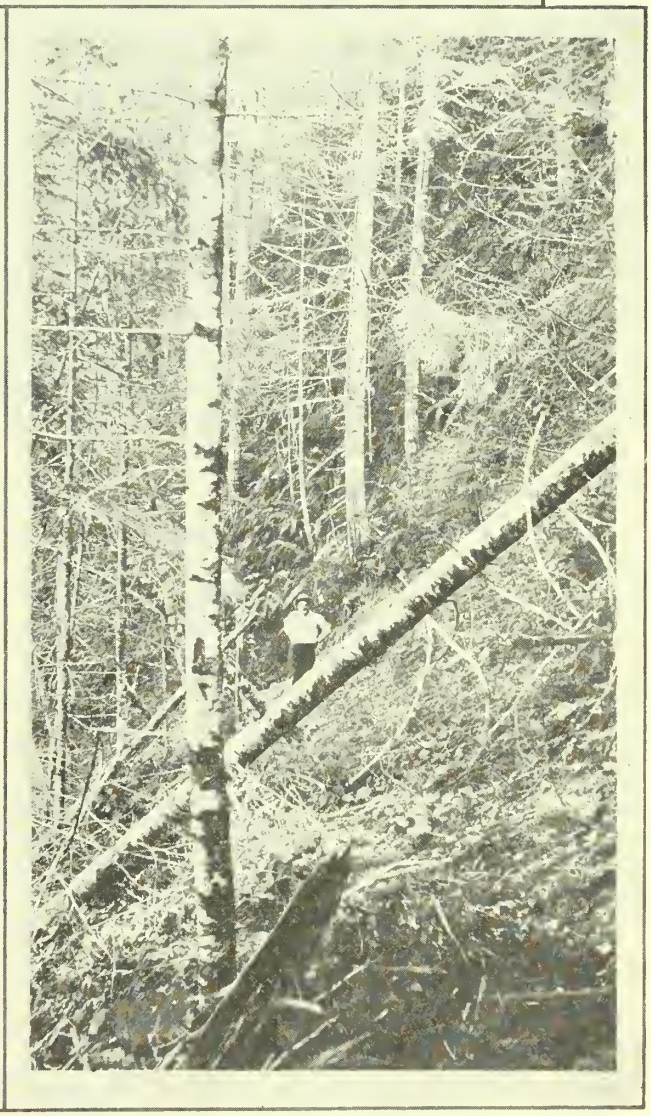
A CONCRETE CULVERT ON MOUNT HOOD LOOP, A FOREST ROAD.

NEED FOR FIRE FIGHTING ROADS.

But more important than any of these reasons for the construction of forest roads, is the great need of forest fire-fighting roads. To those who have not seen forest fires, particularly in the Northwest, the colossal loss of timber annually can not be realized. Hundreds of fires occur annually in the group of 150 national forests. The duty of the Forest Service is to extinguish these fires as quickly as possible; the secret of successful fire fighting is to arrive in time, hence the need for roads. In the months of July, August, and September every man in the Forest Service must be ready at all times for immediate service against the fire enemy. Two things are most feared, an excessive number of small fires due to lightning, of which several are sure to get beyond control before they are extinguished, or fires within the heart of the most remote and inaccessible forest areas. Sometimes both these worst conditions occur at once. Many will recall the devastating fires of 1910 which were stopped far up the north fork of the Flathead by a miraculous snow fall on August 27. Similar conditions have since threatened the Northwest, notably in 1917 and 1919. To combat these fires the Forest Service has requested the Bureau of Public Roads to construct such roads as the North Fork Flathead, running 30 miles through the Blackfeet Forest to the Canadian boundary; the Yaak project, 25 miles long from Sylvanite through the Kootenai Forest, terminating also at the Canadian boundary; the Swan River Road, 8 miles long, and the Metaline in Washington, 11 miles long. All of the roads in the forests are fire-fighting roads, but 12-foot light built roads of the Yaak type are specially designed for fire fighting and have already done their bit in preventing the spread of serious fires.

In the area of Idaho north of the Salmon River and between Missoula, Mont., and Lewiston lie the Lolo, Bitterroot, Clearwater, Selway, and Nezperce Forests, with a total area of 6,000,000 acres. Here are probably the greatest bodies of white pine timber in America; and as no roads penetrate the region, the fire hazard is alarming. So, a 100-mile road known as the Lolo Pass National Forest Road along the trail of Lewis and Clark has been begun. This road will join Missoula, Mont., with Lewiston, Idaho, through an uninhabited region that has already been surveyed and abandoned by two railroads. For 12 miles the line follows the Black Canyon of the Locksa River, where provisions for survey parties are "back packed" from the Powell Ranger station, 27 miles west of Lolo Pass. Construction is under way above the town of Kooskia, Idaho, where a 640-foot bridge over the North Fork of the Clearwater has been finished and also 20 miles of road. The road will be narrow at first,





TOP, FIRE SWEPT FOREST. ADEQUATE ROADS WILL DO MUCH TO PREVENT THIS TREMENDOUS WASTE OF TIMBER. LOWER LEFT, A FOREST ROAD CLEARING IN THE QUINAULT NATIONAL FOREST. LOWER RIGHT, CLEARINGS THROUGH FORESTS LIKE THIS OFTEN MUST BE MADE IN BUILDING ROADS.

BURROS BRINGING IN RICH COPPER ORE OVER THE OLD CLIFTON-SPRINGERVILLE TRAIL IN ARIZONA. THE NEW FOREST ROAD BETWEEN THESE TOWNS WILL DEVELOP LARGE COPPER MINES.

but its lines and grades will be determined with a view to eventual widening; and it will serve as the shortest northern interstate road between Montana and the Columbia River, Spokane, Portland, and Seattle.

Many other fire-protection roads have been begun or built since the passage of the Federal-aid road act of 1916. Such are the 30-mile Coram Spotted Bear in Montana, and the North Fork Payette, 20 miles long, in south Idaho. The construction campaign began with an attack on the mountain passes and the impassable sections of interstate highway at most remote points.

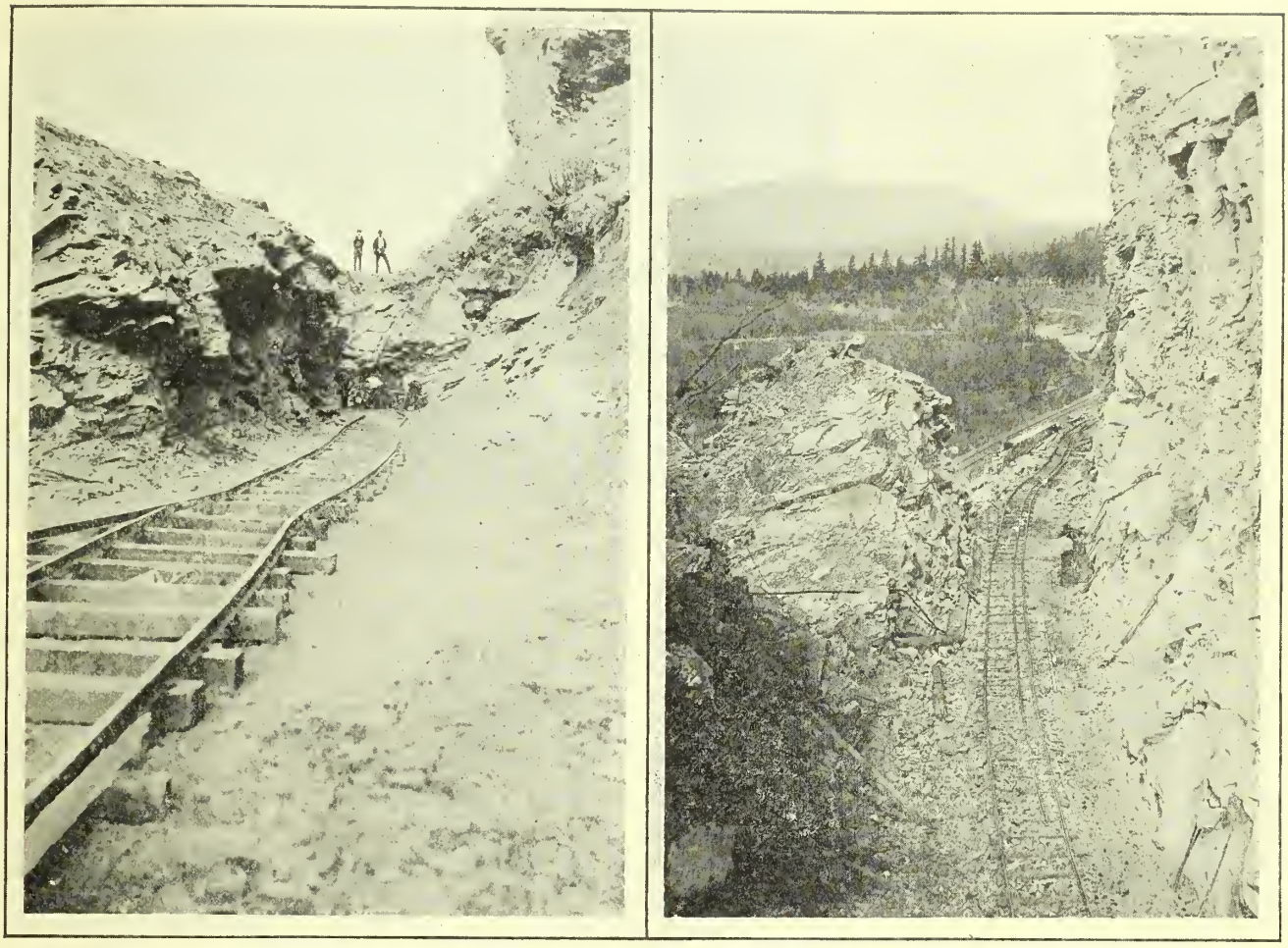
IMPORTANT FOREST ROADS.

The first forest road contract was let in March, 1918, for the Alberton Road in Montana. This is a section of the North Pacific Highway along the Rainbow River west of Missoula, which replaces an almost impassable road on the opposite side, and will connect all western Montana with Wallace, Idaho, and Spokane, Wash. The project is 60 feet above the river and required 6,600 cubic yards of retaining wall in about one-half mile.

On this same interstate highway in Idaho was the notorious "Fourth of July Canyon Road" in the Coeur d'Alene National Forest, where Capt. Mullan passed on July 4, 1865, and inscribed the great fir tree which still stands. Twelve miles of this old trail has just been reconstructed at a cost of about $200,000, and for the first time in the history of north Idaho a good road exists through the difficult region between Spokane and the Coeur d'Alene mines. From the hills on this highway are extraordinarily beautiful views of Lake Coeur d'Alene.

Proceeding farther west on the north bank of the Columbia River Highway in the Columbia National Forest between Cooks and Collins in Washington was 6½ miles of impassable road. This project lay so close above the railroad that material blasted from the basalt ledges had to be very carefully handled to prevent accident. One 600-foot through cut in rock 80 feet above the track practically overhung the rails. It was 30 feet in depth at the maximum point and required 11 months of continuous work to excavate a road 20 feet wide. The finished road is surfaced with gravel and carries a large traffic. Eventually it will be surfaced by the State of Washington with concrete as a part of the interstate highway between Portland and the east via the Northern route.

Passing into Oregon, between Portland and the California line, south of the old stage station at Canyonville, lay possibly the most difficult section of the Pacific Highway. Here a dangerous, crooked, and at times impassable road wound up Cow Creek Canyon and across a low summit to connect with Galesville. Twelve miles of this road has now been thoroughly graded at a cost of approximately $210,000 and will be surfaced by the State of Oregon. Over the canyon on this road will be built the first concrete arch on a national forest road with a 130-foot span. The McKenzie Pass Road between Bend and Eugene in Oregon has been mentioned. Contracts for 30 miles of this 70-mile road have already been let, and the work is well along. A most obstinate section, which will begun shortly, lies on the summit of the Cascade Range at an elevation of 5,000 feet. Here the most recent lava flow in the United States has covered an area many miles in extent. This lava field terminates along a definite line, a part of which is followed by the new forest road and to motorists the appearance of the entire area suggests that the flow might have just occurred. Across this lava flow the construction will



THE COOK-COLLINS, A NATIONAL FOREST ROAD. LEFT, AT WORK ON A ROCK CUT. RIGHT, THE ROAD COMPLETELY ROUGHED OUT THROUGH THIS CUT.

be entirely in rock and one location is no worse than another in point of difficulty.

SPECTACULAR KLAMATH PROJECT.

In California perhaps the most spectacular forest road is the Klamath River project, 42 miles in length, within the Klamath National Forest. The road follows a deep canyon on the hillside, at times passing through stretches of solid granite. It will be 12 feet wide and will open to travel the country between Yreka and the sea for the first time. Along this river a few Indians of the Klamath tribe are living in almost original primitive conditions. A similar project is on the Trinity River in the Trinity National Forest.

In the Southwest are some forest-road projects of great necessity and difficulty and of extraordinary interest. One is the Oracle-Apache Camp project, 30 miles long, in the Coronado Forest in southern Arizona. Work is now in progress at the cost of $11,000 per mile. Part of a cooperative project known as the Clifton-Springerville passes through copper ore so rich that one cut is visibly green. Isolated sections of the project will be in difficult rock and the history of the entire project is a story by itself. In both Arizona and New Mexico are similar projects at high altitudes. In New Mexico is the Glorieta-Panchuela project, a 12.8-mile section of the Santa Fe trail, to cost over $100,000.

To the north in Colorado in the San Juan Forest occurs one of the most spectacular of all of the forest-road projects. This is a 50.5-mile road connecting the towns of Durango and Silverton, passing over two summits at elevations between 9,000 and 10,000 feet. Here no adequate road has ever existed and a new location is required for a large part of the way. From the south pass the road plunges into the Lime Creek Canyon through solid rock for a mile and a half, to rise again to an elevation of 10,000 feet above the mining town of Silverton, from which it descends for the most part on a 5 per cent grade. This road has already been under construction by day-labor forces for two seasons. Thanks to steam shovels and power drills it will probably be completed in 1921. The estimate is approximately $450,000.

In Utah many forest-road projects pass across the mountain ranges running north and south and will afford connections between valleys that never before have been in direct communication. A section in the

Manti Forest between Ephraim and Orangeville rises to an elevation of 9,000 feet, and 4 miles is costing $52,000 for a 12-foot graded section. Similar roads in Utah are the Heber-Fruitland in the Uinta and the Logan-Garden City in the Cache Forest.

In southern Idaho occurs the Ketchum-Clayton project in the Sawtooth National Forest across the Galena Summit on the Sawtooth Highway of Idaho. This road leads into the Stanley Basin country of central Idaho, which is said to be the greatest big-game region existing in the United States. All of these roads are links either in interstate highways or interstate systems.

BOWLDER EXCAVATION ON THE MONARCH PASS ROAD.

ROADS UNDER CONSTRUCTION.

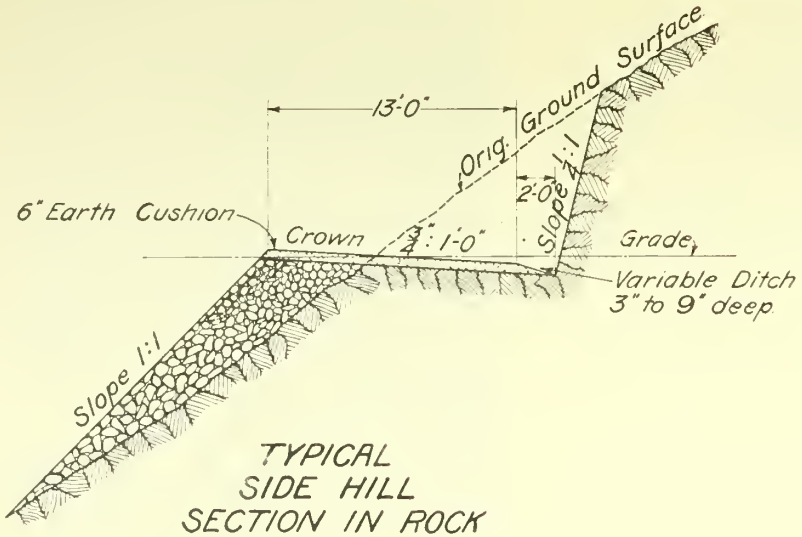
Over 150 miles of National forest roads are also under construction leading into the National parks or forming connecting links between these parks. In Montana four National forest road projects on the direct route from Glacier Park to Yellowstone Park lead for 36 miles over the Little Belt Mountains in Meagher and Cascade Counties, between Great Falls, Helena, and Livingston. Between Glacier Park and the summit of the mountains on the west an 8-mile project in the Lewis and Clark Forest is under construction. Up the West Gallatin River in southern Montana in the Gallatin Forest are 20 miles of road all surveyed and partly constructed at an estimated cost of $84,000. This road will lead into the Yellowstone Park by way of Yellowstone, passing some of the most interesting scenery immediately adjoining the park. On the south in the Targhee Forest are 47 miles leading from Warm River past Henrys Meadows into Yellowstone and forming the last link from the south to our oldest national park. This road will pass close to the Buffalo River and Big Springs, the headwaters of the north fork of the Snake River, where the full-fledged stream springs from beneath the solid rock. In Oregon a 22-mile project between Prospect and the boundary of Crater Lake National Park, in the Crater National Forest, when completed, will for the first time afford tourists opportunity to visit one of the most unique spots in the world. Here, 6,200 feet above the sea, is matchless Crater Lake, unbelievably blue and deep, 2,000 feet below the oval rim of the crater of what must have been one of the greatest volcanoes in the world.

FEATURES OF CONSTRUCTION WORK.

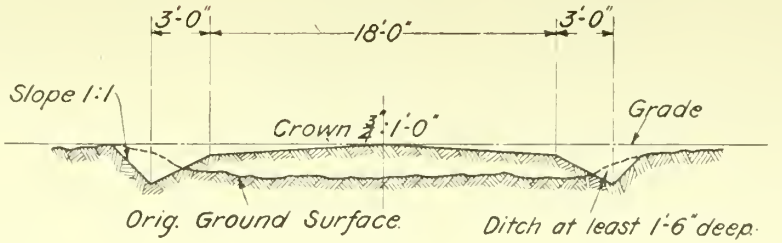
The construction items arising on many of these forest road projects present interesting and unique features. Clearing and grubbing varies from the dense, heavy timber of the Olympic Peninsula in Washington to the grubbing of light sagebrush and cactus on the desert in Arizona. The corresponding prices range from $3,500 per mile to $250. On the Quinault project were trees 8 and 9 feet in diameter. Such clearing becomes a standard logging operation with steam donkey engines. Similar conditions exist in Alaska. Grubbing of the enormous stumps leaves great craters in the grade which often require recross-sectioning to determine changes in quantities.

A FOREST ROAD SURVEY CAMP.

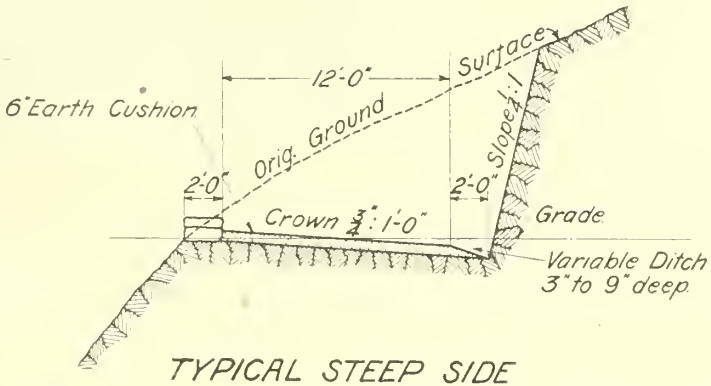
Rock excavation sometimes averages as high as 4,000 yards to the mile on a 16-foot road. It is of all kinds, from bowlder slides, consisting of innumerable masses of rock, which will average several cubic yards in volume, to the basalt cliffs of the Columbia River with vertical hexangular columns from 6 to 60 feet high. Some of the hardest granites occur in Colorado; but even these are not more expensive to work than



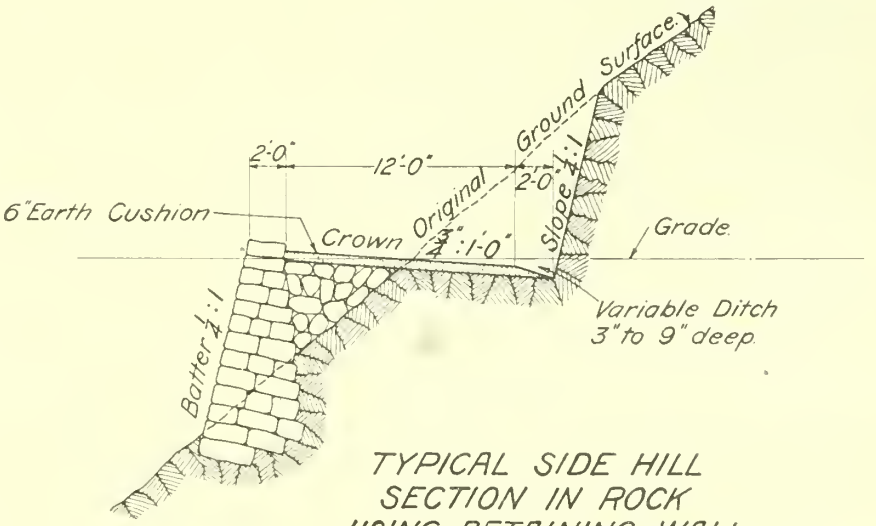
TYPICAL
SIDE HILL
SECTION IN ROCK
(One Way Crown)



TYPICAL
TURNPIKE SECTION.
(Two Way Crown)



TYPICAL STEEP SIDE
HILL SECTION IN ROCK.
(One Way Crown)



TYPICAL SIDE HILL
SECTION IN ROCK
USING RETAINING WALL
(One Way Crown)

TYPICAL SECTIONS OF FOREST ROADS.

the hard conglomerate or cemented gravel caliche of Arizona and New Mexico, upon which blasting has the minimum effect.

Blasting of rock is taken as a standard item on the western mountains, and the "station gang" of cooperative laborers bidding per 100-foot station or per cubic yard is an institution recognized by all contractors. These men attack the ledge in various ways. Sometimes they use the deep "coyote hole," burrowing 30 feet into the rock with a tunnel large enough to permit a stooping man to enter with a wheelbarrow. Sometimes the hole is smaller, 8 or 10 feet in depth and less than a foot in diameter. Such a hole is known as a "boot jack." One "coyote hole" on the Cooks-Collins Road in Washington brought down 2,000 yards of rock with 1,700 pounds of black powder. On the Canyonville-Galesville job in Oregon batteries of small "coyote holes" 15 feet deep at intervals of 15 feet were shot for distances of two or three stations at a time. The effect was to blow out the base of the side hill prism into canyon and permit the top to drop into its place. The mass was then thoroughly broken and could be handled by a steam shovel.

Along the Klamath River in California section gangs of Greeks are at work using TNT. In the upper reaches of the Clearwater in Idaho on the Kooskia-Lowell project station gangs have worked throughout the past winter. Some of these men at times have reported the extraordinary figure of 20 cubic yards of unclassified material per man per day.

The Bureau of Public Roads specifications classify all excavation as either ledge rock or "common," and these specifications are coming to be adopted by several States. During 1919 approximately 2,000,000 cubic yards of "common" were bid in District 1, at an average price of 78 cents, and 400,000 cubic yards of rock (the Government furnishing TNT) were bid at $1.69.

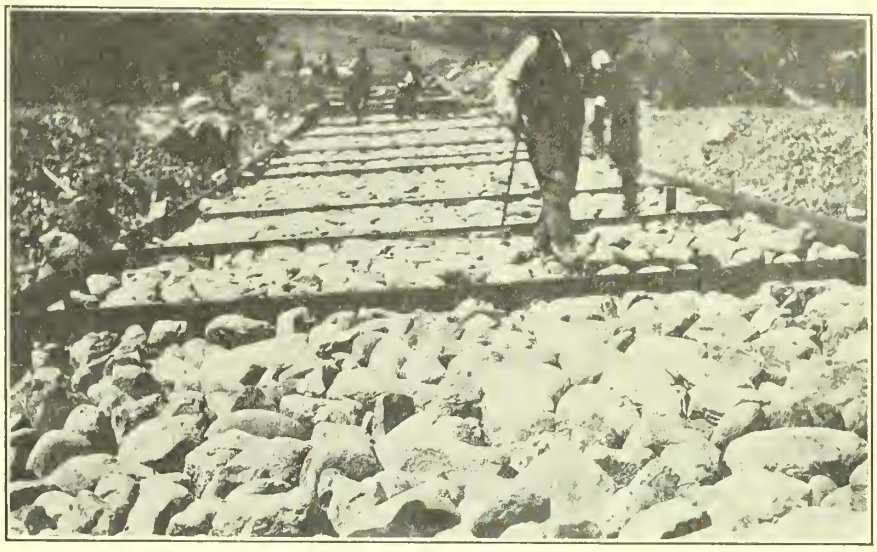
STATEMENT OF COMPLETED PROJECTS, APRIL 20, 1920.

District.	State.	Project.	Length.	Total cost.	Cost per mile.	Weighted average cost per mile by States.
			Miles.			
1	Oregon	Canyonville-Galesville, section 1	9.9	$210,739	$21,287	$13,660
1	.....do	Canyonville-Galesville, section 2	1.1	54,395	49,450	
1	.....do	Flora-Enterprise	12.9	88,398	6,852	
1	.....do	Middle Elk	2.65	9,142	3,450	
		Total, Oregon	26.55	362,674		
1	Washington	Blewett Pass, section 3 and parts 2, 4, and 5	8.4	183.779	21,878	19,768
1	.....do	Cooks-Collins	4.7	135,126	28,750	
1	.....do	Little White Salmon	.8	4,790	5,988	
1	.....do	Quinault Lake (south)	2.5	39,277	15,711	
1	.....do	Republic-Wauconda	3.4	28,439	8,364	
		Total, Washington	19.80	391,411		
		Total, District 1	46.35	754,085		
2	California	Workman's Bar Bridge*	341 ft.	6,192	.....	9,650, not incl.*
2	.....do	Trinity River	4.7	58,193	12,366	
2	.....do	Klamath, Orleans-Somes Bar Section	7.4	164,750	22,263	
2	.....do	Laguna Road	14.6	41,820	2,864	
2	.....do	Hawkins Bar Road and Bridge*	1,486 ft.	17,557	.....	
2	.....do	Salmon River (Forest Service)	4.0	14,000	3,500	
2	.....do	Salmon River (B. P. R. prior 1920)	1.0	27,151	27,151	
		Total, District 2	32.17	329,663		
3	Colorado	Nederland-Ward	10.5	54,700	5,210	5,092
3	.....do	Rabbit Ears	8.94	42,860	4,794	
3	.....do	Sedalia-Decker Springs	14.82	76,902	5,189	
		Total, District 3	34.26	174,462		
6	Arkansas	Ozark Road	33.85	85,000	2,511	2,511
8	Florida	Crestview-Camp Walton	28.0	94,015	3,358	3,358
11	Montana	Alberton	4.1	63,361	15,454	6,681
11	.....do	Belt Creek	18.89	145,121	7,682	
11	.....do	East Fork	5.09	18,926	3,718	
11	.....do	Sheep Creek, section 1	4.05	25,983	6,416	
11	.....do	Swan River, Lake Section	8.0	14,702	1,838	
		Total, Montana	40.13	268,093		
11	Idaho	Fourth of July, section 2	3.0	27,372	9,124	8,634
		Total, District 11	43.13	295,465	.....	
12	Idaho	North Fork-Payette	19.9	170,341	8,560	
		Total, Idaho	22.9	197,713		
12	Nevada	Tonopah	13.9	45,000	3,238	3,237
		Total, District 12	33.8	215,341	.....	.....
13	New Mexico	Highrolls Weed, Sections A and B	7.52	46,286	6,155	5,783
13	.....do	Tijeras Canyon	4.70	24,386	5,189	
		Total, District 13	12.22	70,672	.....	.....
		Grand district total	263.61	2,018,703	.....	.....
		Total average cost per mile (not including projects marked *)	.....	.....	.....	7,581

SURFACING AND DRAINAGE.

Up to the present time none of the forest roads has been surfaced except with fine crushed rock or gravel. The construction therefore consists in the installation of adequate drainage structures and the grading and finishing of the road to the necessary standards demanded by its immediate future duty. Typical cross sections of the forest road are shown in the illustration. Owing to the fact that many of the roads lie in the canyons of mountain streams, side-hill construction prevails. It has generally been found that it is cheaper and better to "bench in" the road rather than to construct retaining walls. At times conditions require the construction of such walls. Dry walls are built with the base six-tenths of the height, and if in excess of 16 feet in height the bottom courses are laid in cement mortar.

Drainage structures of logs are necessarily used in many remote regions. Cedar log culverts and cedar log cribbing are regarded as having great durability. Concrete pipe can be used only within reasonable haul of shipping points, and consequently corrugated metal pipe is found desirable for the longer hauls. With the exception of the more important bridges occurring on projects which are parts of State highways, the superstructures of bridges are of the wood Howe Truss type. On the Quinault River and also on the Salt River in Arizona riveted steel bridges are under construction, and several steel bridges have been built in California. Log crib piers and abutments are extensively used with rock "back fill" and give excellent satisfaction.



CONCRETE FORD AT "MEDDLER'S WASH," SALT RIVER-PLEASANT VALLEY FOREST ROAD, ARIZONA.

CONCRETE FORDS FEATURE.

A feature in the construction of the southwest area is the concrete ford in the arid regions which are subject to cloud-bursts. On the Salt River-Pleasant Valley project in Arizona are a number of these fords built 16 feet wide and nine-tenths of a foot deep. These fords are constructed with "one-man" stones covered with good concrete, and have cost in the neighborhood of $4 per square yard 30 miles above Globe in Arizona.

Interesting studies are underway to determine the relative advantage and economy of the use of steam shovels on national forest road projects as against the handwork of the station gangs. It has already been well established that although a wider road results in most cases with the steam shovel excavation the more workmanlike job follows the station gang method. Contractors using the steam shovel prefer to "borrow and waste" rather than end haul, as it proves economy to them in the end. The station gangs do not remove a surplus yard of material if it is possible to avoid it and leave their banks in excellent shape; also the slower construction of the fills results in a more stable embankment. This is desirable, since it is entirely impracticable to construct fills on heavy mountain excavation by the layer method. Fills are overcast and must be allowed to settle before surface operations can be attempted.

At intervals throughout the West are localities where small, local contract outfits with wheel scrapers and horses are available for grading operations. Contractors are frequently

THIRTY-FOOT BRIDGE ON CRIB ABUTMENTS, TRINITY RIVER ROAD, TRINITY NATIONAL FOREST.

glad to sublet portions of the forest road projects to such outfits.

The table of completed projects gives a comprehensive view of the 263.61 miles completed on April 1, 1920. There are 65 projects with a total of 851.7 miles now under construction in addition to those listed in this table. Surveys have been made for 2,543 miles, and plans have been completed for the greater part of this mileage.

FOREST TRAILS AND MINOR ROADS.

In addition to the road mileage which has been mentioned above, the Forest Service has constructed many miles of forest trails and minor forest roads from the 10 per cent fund and from approximately 25 per cent of the other Federal-aid funds and will continue this work during the present season. Projects now surveyed will require all the available Federal-aid money that has been appropriated except the last three installments of the Federal-aid road act of 1916. The $3,000,000 from this source will give less than $100,000 annually to each of the Western States.

In Alaska approximately $500,000 worth of work is mapped out and partly completed in the Chugach and Tongass Forests. There are 2.4 miles on the Seward Kenai Lake project, 3.2 miles on the Juneau-Eagle River, 6 miles on the Portege Road, and 3.5 miles on the Ketchikan-Wards Cove project. All these projects are still under construction and many miles of additional surveys will be run during the coming season. The Alaska survey and construction seasons are extremely short and some of the features of actual construction are unique. In many localities there is a cover known as "muskeg" which is a sort of decayed moss and humus varying in depth from a few inches to 10 feet or more. Grubbing operations along the shore require the use of heavy donkey engines mounted on scows. As rapidly as possible road-building equipment, including logging machinery, drilling apparatus, and trucks, is being delivered to Juneau, Ketchikan, and other points.

The national forest road program during the past four years has become well defined as one of the road-building requirements of the entire West and State programs of construction are planned in accordance with it, in order that through routes may develop uniformly throughout the several States. During the season of 1919 there were employed approximately 400 engineers and field assistants in the 11 Western States and it is expected that an equal number will be required before the present season's program is completed.

NEW MEXICO CONTRACTS.

It is estimated that about $1,000,000 worth of road-building contracts will be let by the State highway department of New Mexico during July. The summer will be the busiest one known in that State in road construction, especially in roads aided by the State.

HOLD LIBERTY BONDS.

Your fulfilled desires MAY NOT bring you full satisfaction; your Liberty Bond WILL bring full return of principal and interest if you hold it.

If you sell unnecessarily now, in the face of a temporary decline in price, you will not get full value either in money or satisfaction of desires.

Your Liberty Bond is as safe and sound as the Nation itself. Hold and buy more.

MONTANA ROADS.

Road construction is now under way in Montana for which the aggregate amount of the contracts is about $4,000,000. Of this amount contracts for $3,250,000 were let last fall. The State highway commission is working to add another million to the contracts for this year.

TO VOTE IN HIGHER INTEREST.

It has been decided to present to the voters of California at the November election the question of raising the rate of interest on the $40,000,000 worth of bonds voted last year from 4½ to 6 per cent. It has been found impossible to sell the bonds at the rate named in the enabling act and in the proposition submitted a year ago, and unless the rate is increased road construction under the bond issue will have to be postponed indefinitely. The Oregon plan is favored, providing for a maximum rate of 6 per cent, the rate to be fixed at the time of the sale of the bonds.

FEDERAL AID IN KANSAS.

The Kansas State highway commission has approved highways aggregating 461 miles for Federal aid. These highways represent a probable cost of $25,000,000. Contracts have been let for 162 miles, the cost of which aggregates $4,875,000. Counties are going ahead with their preliminary road work in anticipation of increased Federal aid.

There are now in file petitions for 1,345 miles of road, the estimated cost of which is in excess of $50,000,000, granting Federal aid stopped when the total reached nearly $8,000,000, the amount allotted to Kansas.

THE SELECTION AND COMPARISON OF FEDERAL-AID ROAD TYPES.

By E. W. JAMES, Assistant Chief Engineer, Bureau of Public Roads. [1]

IN the handling of Federal-aid projects the first point at which purely technical and administrative questions come squarely into contact is in the selection of the type of surface. Very frequently this contact is one of opposition. An ideal condition at this point can only exist when purely technical considerations control, and for this reason there is little hope that the ideal will ever be approximated. Furthermore, it would perhaps be unfortunate for the engineer if he were faced suddenly at the present time with such an ideal condition, for one of the large and still open questions in highway engineering is the selection of type.

Were the engineer thrown back entirely upon technical considerations, it would be found at once that data are lacking on which to come to any definite conclusion. There is some difference of opinion existing in regard to the general merit of the several types. There is little or no unity of opinion as to the service value of the various types under given conditions of traffic and no more uniform views regarding the probable length of life of the severa types. On the basis of cost over a period of years, two engineers in one of the large State highway departments have recently published articles with almost opposite conclusions regarding the order in which the higher types of pavement can be placed on the basis of ultimate economy. Data are simply not available for a purely technical answer to the question: What type of surface will give the best results under a set of given conditions?

ADMINISTRATIVE CONSIDERATIONS.

We are, however, doubtlessly moving toward the time when we will be able to make an intelligent determination of types on purely technical grounds, and the Bureau of Public Roads as the inevitable clearing house for such information, and as the only governmental organization having at its disposal funds and personnel for conducting the necessary experiments, should and will take a leading part in the necessary research to establish this detail of highway engineering on a much firmer basis than it now rests. Until such time, however, as the results of extensive investigations become available, and no doubt thereafter, it will be necessary to admit several important administrative considerations to a place when types of pavements are under consideration.

First, there are the exigencies of construction to be considered. This involves engineering administration that often meets imperative requirements and results in substantial economies. The present Federal-aid program carries a large number of projects which classify to-day as earth, sand-clay, and occasionally gravel, but which are avowedly to be completed later by the construction of more adequate surfaces. In some cases the proposed future work is a part of the original plan, but in most of the cases the work is confined to grading and necessary drainage with only such surfacing as may be required to carry traffic during a more or less short interval while the embankments are settling and reaching a condition when expensive pavements may safely be constructed upon them. In a great many projects of this kind, however, no definite plans have yet been made for the surfacing, and such questions as selection of type and raising of funds are postponed more or less indefinitely. The result is that for the present, engineering administration fixes our type as earth, sand-clay, or gravel.

Frequently in planning improvements, it is impossible at any one time to secure the necessary funds to carry out high-type work. It is quite obvious from an examination of the present Federal-aid records that in many cases counties are making their supreme financial effort to provide for the construction of a sand-clay or gravel road. Under conditions of traffic where it is obvious that a higher type of surfacing should be selected, such financial considerations which are purely administrative in nature have the effect of determining the type, regardless of what the highway engineer may recommend. As in the previous case, the final selection of type is in effect postponed until more funds are available.

Finally, and by no means least, we have the influence of local opinion which must be met and given due consideration. It is a question sometimes whether this opinion should be dignified by the name of "administrative consideration" or not, but the fact remains that it is an influence to be reckoned with wherever it occurs. The efforts of the engineer in this case should of course be in the direction of influencing the local opinion, but he is often one among many, and as he is not paying for the work his recommendations are more likely than not to be disregarded. It is at this point also that the promotion work of men having materials, equipment, or proprietary types for sale exercises its strongest influence on the selection of types. As in the other cases referred to, evidence can be found on almost every page of the Federal-aid record of projects being determined as to type, as well as to location and other details, by the influence of more or less interested local opinion.

[1] Paper read before conference of District Engineers.

DETERMINING SUITABILITY OF TYPES.

The purely administrative matters referred to thus far will doubtless always be with us, and the time is far distant when purely technical considerations will control in the selection of surfaces, but there has been nevertheless considerable work done in the direction of establishing factors for determining, with some approximation at least, the suitability of road types for service under given conditions.

For a number of years the Bureau has constructed and maintained experimental roads. Probably the most valuable work done in the course of the experiments has been on surface treatments, and considerable data, incomplete to be sure and only partly conclusive, are available.

In these studies we find, for instance, that a water-gas tar preparation applied as a cold surface treatment, maintained under patrol, will carry 925 gross tons of traffic per day, and under this traffic the maintenance will be the third in order of economy of seven experimental sections. This same section was destroyed beyond the point of any reasonable maintenance by a traffic of 1,130 gross tons per day. The nature of the effect of 1,130 tons per day was that of an overload which no amount of maintenance could remedy. The average life of a retreatment of this material is eight months. A hot tar surface treatment stood up satisfactorily under 1,325 gross tons daily average and was the sixth in order of economy in the same group of seven experiments.

There is available considerable undigested data of this kind covering seven different experimental sections. This material is now in the process of being analyzed and will probably supply valuable data for the selection of surface treated macadam. It may enable the engineer even to differentiate hot and cold treatments, tars and asphaltic oils, and possibly different asphaltic oils.

The information will in general take the form of the maximum gross tonnage-endurance of the type, the average life of retreatments, the cost of maintenance per ton of traffic, and details of successful maintenance operations.

PROBABLE LIMITING ENDURANCE.

Up to the present time the determination of type has rested largely on the judgment of each individual, so far as technical details are concerned. There is little or no material of value in the literature of highway engineering nor in the engineering press relative to the question. Engineers have written all around the subject, but have generally refrained from committing themselves to figures. We find a few attempts however, to state the probable limiting endurance of types in terms of traffic and the following indicates the result of one such attempt. The table may be headed "Limiting Economic Traffic on Types of Road Surface."

	Light wagons.	Heavy 1-horse wagons.	Heavy 2-horse wagons.	Automobiles.
Good gravel	50–75	25–30	10–12	100
Oiled gravel	.....	.....	Greater than	100
Do	75–100	30–50	20	500–700
Waterbound macadam	100–150	175–200	60–80	75
Hot oil surface treated waterbound macadam	250–300	75–100	25–30	1,400
Do	.....	Narrow tires, 100	Narrow tires, 50	Trucks, 50
Tar surface treated waterbound macadam	30–50	25–30	10–15	1,800

An older attempt at stating the limiting traffic which various types of pavement may be expected to carry economically was made by the committee on standards of the American Road Builders' Association in their report of 1915. Their tabulation follows:

Item.	Horse drawn, steel tires.		Self-propelled, rubber tires.		Self-propelled, steel tires.
	Light vehicles	Heavy vehicles, wagons, trucks.	Passenger automobile.	Motor trucks and busses.	Steam lorries and tractors.
Earth (sand)	100	75	100	.....	.....
Gravel	100–200	75–150	400 up	.....	1
Cold oil surface treated gravel	100–200	75–150	400 up	10	1
BITUMINOUS MACADAM OR CONCRETE.					
Water-bound macadam (surface treated)	100–200	75–150	100–400	10	1
Water-bound macadam (cold asphalt, oil surface treated)	100–200	75–150	100–400	10	1
Water-bound macadam (hot surface treated)	100–200	75–150	400 up	10	1
Water-bound macadam (cold tar surface treated)	100–200	75–150	400 up	10	1
Bituminous macadam (soft stone)	200 up	75–150	400 up	10–20	1
Bituminous macadam or concrete (hard stone)	200 up	150 up	400 up	10–20	2–6
Concrete	100–200	75–150	400 up	10–20	.....
Vitrified brick stone sets or wood block	200 up	150 up	400 up	20 up	6 up.

It is noteworthy that the above indicates that certain types of surfaces may be depended upon to carry somewhat more than is indicated by the careful experimental work of the bureau. But the range of type in the first table is so limited that it is of little general use, although it fairly represents the best data of the kind available. The table furnished by the Road Builders' Association is altogether too uniform in its enumeration of traffic and for steel-tired vehicles on the lower types of surfaces is much higher than appears to be warranted.

With respect to heavy trucking, the observations of this bureau are that the effect of trucks rated heavier than 3 tons is generally seriously destructive of any type of pavement designs customarily used on rural roads up to 1917. Further, the destructiveness varies directly with the speed, but probably in greater ratio. It appears that constant use of a few trucks per day, if they are heavier than 3 tons and run at high speed, say 25 to 35 miles per hour, is sufficient to cause high-type pavements of designs current in 1916 to fail as by overload. It is not a question of adequate or economical maintenance in such cases, but of out-and-out pavement failure.

IMPACT A DESTRUCTIVE FORCE.

Within the last two years we have been compelled to give recognition to a new destructive force affecting road surfaces. Impact, almost never formerly considered by the highway engineer, is now a force to be reckoned with. It has a close application to the determination of types for certain kinds of traffic, and as high-speed motor trucks are increasing in number rapidly and becoming more generally used, the question of the effect of impact is a serious problem. The bureau is at work determining the force of impact developed by trucks under a variety of conditions. Parallel with these investigations impact test experiments are now ready which, it is hoped, will indicate to some known degree of accuracy the amount of impact which different types of pavement will successfully resist. The correlation of these two sets of experiments should furnish some data useful to the solution of the question: How much truck traffic will a given type stand without failure?

Other experiments to determine the effect of abrasion on pavement surfaces are also underway, and these will furnish further data useful in the selection of types. Obviously, if these experiments are fruitful in results, the engineer will be in a much better position a year from now to face the purely technical considerations involved in the selection of pavements.

ALTERNATE DESIGNS.

On Federal-aid work probably every district engineer has observed that the question of the selection of types is not the only perplexing matter connected with the subject. There has been during the past two years a continual increase in the practice of using alternate designs on projects submitted. This practice was not common when Federal aid was first inaugurated, but beginning with Indiana, in which State the law requires that tenders shall be asked on at least two alternate types, and with Ohio and Pennsylvania, which states adopted a policy of securing bids on alternate types, the practice has rapidly expanded until to-day Federal-aid projects, involving the higher types of design, come to the Bureau more often with alternate designs than with a single type. This fact is borne out by the statistics of Federal-aid mileage. At one time when an examination of the records was made for this purpose 12.8 per cent, representing 963.65 miles, was undetermined. Practically all of this mileage was undetermined because a decision as to the type had not been made and would not be made until after bids had been received. This does not represent all of the alternate work undertaken, as a considerable mileage entered under other types had originally been submitted in alternate form and adjusted when award was made. Obviously therefore, the question of alternate types has become a serious one in mere quantity, and because of the extraordinary questions involved appears likely to result in some very troublesome questions of policy and administration for the Bureau.

METHODS OF COMPARING TYPES.

The problem has come before the Bureau from so many different angles that it appears almost hopeless to attempt a solution along any of the lines heretofore suggested.

In the first place, Illinois has attempted to set up a rational method of comparing types with at least one very interesting result. Although the conclusion reached is not satisfactory to many engineers and certainly not to a large group of material manufacturers, there has, nevertheless, been surprisingly little unfavorable criticism of the Illinois conclusion, either among engineers or in the engineering press. The reason for this is quite clear—for neither the engineers nor the editors have any better data on which to base objections than the Illinois department had on which to base their conclusions, and the attitude of all concerned appears to be very largely one of "hands off." The essential feature of the Illinois conclusion is that, studied as a beam, a pavement cross section wholly of concrete is stronger than black top on an adequate base of concrete. The upper layers or wearing surface of a pavement cross-section in concrete is worth twice as much as a black-top wearing surface. Incidental to this conclusion is the use of an identical mix for a one-course concrete design and for the base of black-top construction. Obviously, a rational analysis of this problem has not been made and would be of very doubtful value. It appears to involve the analysis of a compound beam of elastic material continuously, but not uniformly, supported on elastic bearings, and besides the question of flexure involves consideration of no less than three different longitudinal shears, one in concrete, one in black top, and one in the joint between them. The last element can not possibly be evaluated, and the question of reduced impact, owing to the cushioning effect of the black top, confuses the whole problem.

Another method suggested and used by the State of Pennsylvania in the specification current during 1919 is to establish comparable types on the basis of probable cost. For this reason, Pennsylvania in the standard specifications for 1917, developed designs for such pavements as sheet asphalt, Filbertine and Warrenite, having dimensions which depart from previous customary practice. These designs were built up with the sole end in view of producing a cross-section in each type of substantially equal money value. Obviously, the problem is reduced to a hopeless dilemma by attempting a solution of this kind, because if on the basis of cost a logical solution is attempted it must be revised as the costs of materials vary, but in so doing it becomes distinctly illogical from the technical viewpoint.

Another solution of the problem of comparable and alternate types which has been tentatively followed by this Bureau starts by establishing a list of pavements on the basis of service value. This is purely empirical and indeterminate because it is likely to vary somewhat in the judgment of different engineers. The order in which pavements have been listed by the Bureau is as follows:

Brick on a concrete base.
Sheet asphalt on a concrete base.
Cement concrete.
Bituminous concrete on an adequate base.
Bituminous macadam.
Surface-treated macadam.
Waterbound macadam.
Gravel macadam.
Gravel.
Sand clay.
Top soil.
Earth.

GROUP CLASSIFICATION OF TYPES.

Quite clearly there may be a difference of opinion as to the position of cement concrete and bituminous concrete in the above list, and it is equally clear that a lower type may, by superior detail of design, be made to excel a higher type in the list. The next step, therefore, was to attempt to indicate sufficiently the details of design so that the pavements could be classified in groups. This classification follows:

Class A for heavy traffic:

(1) Monolithic or semimonolithic brick pavement using 3-inch or 3½-inch block on cement concrete base, 4 or 5 inches deep, 1–2½–5, or 1–3–6 mix.

(2) Bituminous concrete, 2 inches thick, on a 6 or 5 inch cement concrete base, 1–3–6 mix.

(3) Cement concrete pavement, 6 inches thick at the sides and 7½ inches at the center, 1–2–4 mix.

Class B for medium traffic:

(1) Bituminous concrete, 1½ inches thick, on a cement concrete base 4 to 5 inches thick, 1–3–6 mix.

(2) Cement concrete pavement, 5 by 6½ inches, 1–2–4 mix.

(3) Bituminous concrete, 2 inches thick, on a 4-inch bituminous concrete base of crushed stone or gravel.

Class C for light traffic:

(1) Bituminous concrete, 1½ inches thick, on a bituminous concrete base, 4 inches deep, of crushed stone or gravel.

(2) Bituminous concrete, 1½ inches thick, a bituminous binder course 1½ to 2 inches thick, on a 4-inch broken-stone base.

(3) Bituminous concrete, 2 inches thick, on a waterbound macadam base 5 inches thick.

(4) Bituminous macadam, 2½ inches thick, on a 5-inch waterbound macadam.

This classification was especially devised as a suggestion for the State of Idaho, and there was included under class A for heavy traffic as a fourth alternate, bituminous concrete, 2 inches deep, on a 6-inch or 5-inch bituminous concrete base of crushed stone. This addition was solely for the purpose of providing in this group a type of surface that did not require water in the building. Consideration of these groups indicates at once that the classification is not of a kind to be generally applicable. Class A pavements would be made considerably heavier in most of the Eastern States and numerous other variations in detail would have to be made for other localities.

So many different questions have arisen regarding the determination of alternate and comparable types that it appears necessary to seek a solution in an entirely different direction. So far we have attempted to establish an equivalency of either cost or service value. It is doubtful whether this is possible in the light of our present knowledge and it appears likely that when further data is available this doubt will be converted into a certainty.

DIFFERENTIALS AMONG TYPES.

It has, therefore, been suggested that an attempt be made to establish normal differentials among the several higher types that are likely to be brought together in competition. This normal differential presupposes the fixing of what may be referred to as a normal base price for each type on a given project, and this will be arrived at by a careful analysis of the materials entering into the construction of the design on the basis of their cost. Given a particular project on which it is intended to solicit tenders for sheet asphalt, modified Topeka, and concrete, the materials necessary to construct each type will be located and the cost of placing them into the work will be analyzed. This will provide for each type a very carefully compiled engineer's preliminary estimate. It need not represent the actual cost, but it will establish a normal basis of comparison and fix the normal differentials that may be expected to exist between various types. This will be done, of course, in advance of the bidding, and the engineer, and assumably prospective contractors, will have advance knowledge of these differentials.

When the bids are opened, if the bid for concrete is below its normal base price and the bid for Topeka is above its normal base price, the concrete would be considered the better bid. If, on the other hand, sheet asphalt, although bid at a considerably higher cost, were below its normal base price, and concrete above its normal base price, the tender for sheet asphalt could logically be considered as the better bid. Assuming, therefore, that in the premises the types have all been established as adequate and reasonable for the traffic likely to develop on that particular project, then the engineer would be logically justified in awarding a contract to sheet asphalt, although it might be the highest bid in dollars and cents. The practical effect of this method is to avoid a decision as to strictly comparable types or designs, and at the same time maintain competition. But that competition is no longer *among the types;* it is a competition of each type *with its normal* or base estimate.

WORKING OUT THIS SUGGESTION.

It is, of course, at once apparent that a suggestion of this kind can only be worked out under very intelligent engineering direction. The policy of blindly assuming costs based on previous averages of bids must be abandoned. Likewise, the custom so apparent now in Federal aid estimates of assuming a single price of $2.75 or $3.50 for surface, regardless of the

type, simply for the purpose of establishing a preliminary estimate will have to be discarded. It will mean that the engineer after having selected his alternative designs will first have to compute the quantities of cement, sand, chips, aggregate, bitumen, filler, and whatever other materials enter into the construction, locate probable sources of suitable materials, and carefully analyze the cost of each one. The organization of a mixer gang will have to be known within a narrow margin, based on the probable method of construction prevailing and likely to continue in the particular locality. Similarly, any construction organization which may be required by the design selected will have to be understood and labor costs analyzed. It is probably not possible to generalize in these matters and estimates would be required for each project coming under consideration.

Whether this scheme is practicable from a business point of view may be open to some question. It has some decided advantages. For instance, it has been noticed that concrete bids when brought into competition with bids for Topeka or Warrenite on a concrete base have a marked tendency to rise until they are only slightly below the Topeka bids. If a differential were established concrete would have to stay down where it belongs or it would be at a disadvantage. The cost of preparing preliminary estimates would be somewhat greater than at present and the estimates could not be based so generally on averages derived from records of past bids as they now are. It is probable also that a somewhat higher standard of preliminary engineering in general would be required to carry out this scheme successfully because there would doubtless arise considerable differences, especially among material men, as to the fairness of the differentials established and the engineer responsible for the computations would have to fortify his conclusions by very skillfully analyzed data.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN MAY, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Arizona	29	Pima	8.852	Concrete	May 3	$347,159.23	$173,579.61
	30	Maricopa	3.000	do	May 6	98,596.08	49,298.04
	24	Coconino	14.860	Gravel	May 26	138,688.00	69,344.00
Arkansas	74	Searcy		Bridge	do	34,650.00	15,600.00
California	59	San Luis Obispo	11.540	Concrete	May 11	311,828.00	155,914.00
	58	Santa Barbara	14.640	do	May 25	440,814.00	220,407.00
	57	Tehama	13.600	do	May 26	241,395.00	120,697.50
Colorado	96	Otero	1.515	do	May 4	76,276.20	36,615.50
	118	El Paso	2.763	do	May 26	135,451.80	55,260.00
	19	Powers	2.024	Gravel	May 28	19,963.07	9,981.53
	59	Bent	10.000	do	do	89,522.01	44,761.00
	86	Larimer	1.386	Concrete	do	56,068.10	27,720.00
	112	Park	0.909	Gravel	do	29,109.05	14,554.52
Georgia	142	Thomas	8.900	Sand clay	May 4	64,350.00	32,175.00
	146	Tift	6.000	Paved	May 7	181,154.05	50,000.00
	137	Bibb	4.000	Concrete	May 11	141,940.99	55,000.00
	144	Macon	3.750	Sand clay	do	8,373.64	4,186.80
	143	Laurens		Bridge	May 25	103,315.88	50,000.08
	150	Washington	8.300	Sand clay	do	62,424.19	30,000.00
	145	Montgomery	12.000	do	May 11	60,434.00	30,000.00
	149	Telfair	9.810	do	May 26	60,370.42	21,000.00
	147	Troup	13.240	Top soil	May 28	121,578.42	50,000.00
	151	Floyd	7.000	do	do	44,218.57	22,109.22
	158	Twiggs	8.990	do	do	48,056.03	21,000.00
	118	Fannin	[1] 1.953	Earth	May 25	[1] 57,500.71	[1] 29,550.75
Idaho	42	Gooding	5.350	Crushed rock	May 4	52,999.54	26,499.77
Indiana	25	Miami		Bridge	May 28	13,007.50	6,503.75
Iowa	68	Dickinson	5.000	Paved	do	247,445.00	100,000.00
	128	Johnson	2.500	do	do	115,060.00	50,000.00
	18	Clinton	[2] 0.721	do	May 7	[1] 820,940.34	[1] 323,813.55
Kansas	57	Marshall	30.500	Concrete or gravel, bituminous	May 3	1,472,927.50	147,500.00
	56	Gray	6.000	Gravel	May 11	69,991.90	28,750.00
	58	Shawnee	7.930	Brick, concrete, or bituminous macadam	May 24	459,415.00	75,150.00
Kentucky	29	Laurel	16.166	Macadam	May 5	275,797 94	137,898.97
	24	Jessamine	3.960	Waterbound macadam, surface treated	May 28	[1] 40,333.55	[1] 20,166.77
Maine	29	Androscogin	5.260	Bituminous macadam	May 7	193,479.00	96,739.50
	28	Sagadahoc	1.340	do	May 11	45,870.00	22,935.00
	34	Oxford	4.570	Concrete	do	188,199.55	91,400.00
Massachusetts	37	Berkshire	1.164	Bituminous macadam	May 4	48,042.50	23,280.00
	38	Essex	2.827	do	May 6	149,699.00	56,540.00
	35	do	4.572	Concrete	May 4	224,455.00	91,440.00
Michigan	37	Hillsdale and Calhoun	11.637	Concrete and gravel	May 28	235,620.00	117,810.00
Minnesota	163	Rock	6.000	Gravel	May 3	40,095.00	20,047.50
	120	Aitkin	8.050	do	do	45,012.00	22,506.00
	164	Traverse	15.400	do	May 4	110,024.20	55,012.10
	131	Douglas	14.070	do	May 5	78,360.70	39,180.35
	98	Todd	19.570	do	May 12	102,740.00	51,370.00
Minnesota	139	Lyon	8.000	do	do	97,020.00	48,510.00
	145	Pope	14.850	do	May 11	105,193.00	52,596.50
	165	Wright	14.000	do	do	130,020.00	65,010.00
	166	do	5.300	do	May 12	48,994.00	24,497.00
	168	Itasca	8.430	Concrete, brick or asphalt	May 11	346,568.64	168,600.00
	129	Clay	27.740	Earth	May 28	109,428.00	54,714.00
	140	Cass	12.600	Gravel	do	83,314.00	41,657.00
	141	do	5.500	do	do	41,470.00	20,735.00
	151	Kittson	15.750	do	do	89,848.00	44,924.00
	155	Polk	13.500	do	do	90,847.35	45,423.67
	167	Hubbard	9.000	do	do	56,930.72	28,465.36
	173	Dodge	3.980	do	do	44,326.70	22,163.35
	174	do	3.000	do	do	43,120.00	21,560.00

[1] Revised statement. Figures given are increases over those given in the original statement.
[2] Revised statement. Mileage given is a decrease from that in original statement.

PROJECT STATEMENTS APPROVED IN MAY, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Mississippi	49	Coahoma	10.680	Concrete	May 3	$320,485.44	$100,000.00
	96	Sunflower	5.180	....do	...do	160,380.00	80,190.00
Missouri	99	Clay	10.600	Bituminous macadam	May 11	253,322.47	126,661.23
	26	Dunklin	8.620	Gravel	...do	118,023.81	59,011.90
	102	Cedar	5.550	Chat	May 28	49,718.60	24,859.30
	108	Grundy	5.000	Earth	...do	41,145.50	20,572.75
	114	Lawrence	8.000	Gravel or chat	...do	18,046.21	9,023.10
	116	Grundy	7.450	Earth	...do	187,877.80	93,938.90
	117	Henry	6.480	Chat	...do	71,694.00	35,847.00
	120	Mew Madrid	3.500	Gravel	...do	61,274.40	30,637.20
	123	Andrew	0.514	Bituminous macadam	...do	11,694.10	5,847.05
Montana	71	Musselshell	0.660	Earth	...do	19,847.00	9,923.50
	109	Stillwater	5.200	Gravel and earth	...do	92,452.63	46,226.31
Nebraska	107	Cass, Saunders, and Sarpy	32.000	Earth	May 3	177,100.00	88,550.00
	149	Cheyenne	36.300	.....do	May 28	137,929.00	68,964.50
	148	Gopher and Frontier	36.800	.....do	...do	141,724.00	70,862.00
New Hampshire	112	Cheshire	0.260	Gravel	May 4	10,000.00	5,000.00
	95	.....do	0.810	Gravel and bituminous macadam	...do	15,000.00	7,500.00
	98	.....do	0.625	Gravel	May 3	11,999.99	5,999.99
	117	Grafton	0.940	Bituminous macadam	May 28	25,000.00	12,500.00
	99	Coos	1.100	Gravel	...do	18,000.00	9,000.00
New Jersey	28	Camden	[2] 4.907	Concrete	May 26	[2] 226,949.54	[2] 98,140.00
	23	Mercer	[2] 0.626	.....do	May 13	[2] 47,295.38	[2] 12,520.00
New Mexico	31	Sierra	4.220	Gravel	May 11	25,457.90	12,728.95
	49	Otero	11.600	Caliche	May 28	77,036.30	38,518 15
New York	45	Orleans	3.300	Concrete	May 6	132,000.00	66,000.00
	62	Chenango	0.750	.....do	...do	74,000.00	19,000.00
	63	Tompkins	4.600	Bituminous macadam	...do	174,800.00	87,000.00
	64	Suffolk	9.200	Concrete	...do	368,000.00	184,000.00
	65	Otsego and Schoharie	10.700	.....do	May 12	428,000.00	214,000.00
North Carolina	140	Robeson	38.500	Top soil	May 3	312,950.00	156,475.00
	136	Dare	7.000	.....do	May 26	52,684.50	26,342.25
North Dakota	63	McLean	10.000	Earth	May 3	31,900.00	15,950.00
	66	Sargent	6.375	.....do	May 5	23,760.00	11,880.00
	94	La Moure	15.000	.....do	May 12	47,080.00	23,540.00
	96	Ramsey	9.000	.....do	May 3	25,300.00	12,650.00
	97	McIntosh	12.000	.....do	May 6	40,020.00	20,010.00
	98	Benson	15.000	.....do	May 3	48,950.00	24,475.00
	99	Griggs	2.500	.....do	May 11	7,480.00	3,740.00
	101	Foster	6.000	.....do	May 26	16,632.00	8,316.00
	102	.....do	3.500	.....do	May 11	9,702.00	4,851.00
	93	La Moure	8.000	.....do	May 28	25,696.00	12,848.00
	39	Grant	0.500	.....do	May 6	[1] 34,000.00	[1] 18,848.42
Ohio	125	Auglaize	2.940	Concrete	May 12	115,000.00	35,000.00
	126	Preble	4.170	Brick	May 11	216,000.00	31,000.00
	109	Clark	6.220	Concrete	May 28	360,600.00	61,000.00
	110	.....do	9.100	.....do	...do	395,000.00	89,000.00
	123	Miami	4.670	.....do	...do	172,000.00	46,700.00
	124	Auglaize	5.306	.....do	...do	220,000.00	72,000.00
	143	Logan	5.600	.....do	...do	248,000.00	85,000.00
	108	Meigs	10.150	Earth	...do	224,000.00	112,000.00
	154	Clermont	3.548	Macadam	...do	104,600.00	39,320.00
Pennsylvania	77	Monroe	7.280	Concrete	May 4	450,572.36	145,600.00
	82	Erie	8.466	.....do	...do	502,789.26	169,320.00
	83	Montgomery	4.907	.....do	...do	265,732.67	98,140.00
	84	Tioga	3.865	.....do	...do	352,523.52	77,309.00
	79	Montgomery	5.655	.....do	May 3	313,752.94	113,100.00
	81	Tioga	3.966	Bituminous or concrete	May 4	354,394.26	79,320.00
	80	Crawford	3.432	Concrete	May 11	221,091.35	68,640.00
	74	Northampton	6.610	.....do	May 25	357,289.57	132,200.00
Rhode Island	10	Newport	2.030	Bituminous macadam	May 7	114,000.60	40,600.00
South Carolina	9	Washington	2.290	Concrete	May 26	125,411.20	45,800.00
	94	Union	3.873	Top soil	May 5	23,521.89	4,200.00
	104	Calhoun	1.200	Concrete or macadam	May 28	70,621.65	23,665.04
South Dakota	55	Deuel	9.600	Gravel	May 3	63,155.40	31,577.70
	58	Codington	18.200	.....do	May 5	122,489.40	61,244.70
	57	Jones	7.580	Earth	May 3	48,338.40	24,169.20
Tennessee	25	Giles	19.087	Bituminous macadam	May 28	519,688.14	259,844.07
Texas	157	Galveston	1.500	Brick	May 3	101,050.40	30,000.00
	125	Liberty	8.518	Gravel	May 6	136,596.44	65,000.00
	151	Bee	21.919	Bituminous	May 7	426,547.86	200,000.00
	152	Upshur	25.900	Gravel	May 11	228,635.77	114,317.88
	49	Nolan	[2] 13.700	.....do	May 18	[2] 43,709.60	[2] 21,854.80
	44	Robertson	[2] 5.500	.....do	May 8	[2] 27,890.50	[2] 13,945.25
Utah	30	Weber	7.371	Bituminous concrete	May 25	268,450.05	134,225.02
Virginia	29	Sanpete	1.230	Hard	...do	[1] 47,160.30	[1] 23,580.15
	79	Stafford and Prince William	0.550	Concrete	May 5	39,710.00	14,000.00
Washington	66	Chesterfield	8.940	.....do	May 4	352,682.00	176,341.00
	68	Grant	3.340	Gravel or crushed rock	May 7	51,475.16	25,000.00
	67	Mason	5.540	Gravel	May 11	118,640.92	59,320.46
	70	Lewis	3.960	Earth	...do	95,140.65	46,000.00
	66	Garfield	7.470	Concrete	...do	215,216.65	100,000.00
	64	Snohomish	0.990	.....do	May 26	39,695.26	19,800.00
West Virginia	97	Marshall	3.000	.....do	May 28	136,643.00	16,843.00
Wisconsin	118	Ashland	1.400	Macadam	May 6	15,468.97	5,400.00
	148	Waushara	4.380	Gravel	May 4	45,093.76	15,557.00
	158	Iron	5.350	Earth	May 11	39,000.00	14,500.00
	132	Marquette	4.600	Top soil	...do	42,211.67	14,950.00
	167	Lincoln	5.520	Gravel	...do	48,000.00	16,500.00
	113	Douglas	5.800	Concrete	May 25	283,417.17	95,275.97
	130	Price	5.510	Earth	...do	55,050.00	18,350.00
	146	Vilas	5.670	Gravel	...do	60,000.18	22,000.00
	170	Oneida	4.660	.....do	...do	45,000.00	15,300.00
	160	Waukesha	2.240	Concrete	May 28	78,577.51	28,300.00
Wyoming	76	Portage	[2] 6.370	Gravel	May 12	[2] 31,019.23	[2] 10,339.74
	86	Johnson	6.477	Selected material	May 11	78,870.00	39,435.00
	75	Uinta	2.489	.....do	...do	18,425.00	9,212.50
	82	Laramie and Goshen	22.861	.....do	May 25	207,240.00	103,620.00
	84	Park	6.951	Earth	...do	56,650.00	28,325.00
	30	Natrona	4.106	Concrete	May 28	180,510.00	90,255.00
	83	Sheridan	14.129	Selected material	...do	153,835.00	76,917.50
	85	Natrona	10.000	.....do	...do	92,125.00	46,062.50
	41	Crook	10.089	Earth	May 26	[1] 47,740.00	[1] 23,870.00

[1] Revised statement. Figures are increases over those given in the original statement.

[3] Withdrawn.

PROJECT AGREEMENTS EXECUTED IN MAY, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Arizona	10	Maricopa		Bridge	May 6	$54,970.74	$27,485.37
	14	Cochise	13.560	Gravel	May 12	112,213.35	56,106.67
	11	do	8.464	Concrete	May 11	297,081.14	148,540.57
	5	Mohave	2.186	Gravel	May 17	76,151.90	38,075.95
	3	Navajo and Apache	.498	do	May 12	[1] 19,725.38	[1] 9,862.69
Arkansas	46	Grant	12.480	do	May 25	32,595.36	12,000.00
	51	Conway	6.030	Bituminous, macadam	do	107,772.28	49,156.00
California	39	Riverside	14.330	Reinforced concrete	May 12	356,735.53	178,367.76
	43	Mariposa	1.280	Earth	do	38,004.14	19,002.07
Colorado	36	Boulder	1.182	Concrete	May 11	46,607.27	23,303.63
	37	do	.814	do	do	47,424.13	23,712.06
	77	Mesa	2.496	do	do	113,743.05	49,920.00
	17	El Paso	2.339	Earth	May 14	53,167.90	26,583.95
	33	Larimer	1.962	Concrete	do	74,494.25	37,247.12
	65	Ouray	1.155	Earth	do	67,775.89	24,698.16
Delaware	2	Sussex		Concrete	May 6		17,290.61
Florida	8	Alachua	11.675	Bituminous, macadam	May 12	204,018.80	102,009.40
	14A	Santa Rosa	6.318	Grouted brick	do	130,158.87	65,079.43
Georgia	56	Gwinnett	12.000	Top soil	do	70,380.56	35,000.00
	88A	Brooks	4.550	Concrete, sand-clay	do	116,223.49	58,111.62
	43	Habersham	4.648	Bituminous, macadam	May 11	20,888.19	10,444.09
	94A	Dooly	7.620	Sand-clay	do	50,180.37	25,090.18
	106	Sumter	3.000	Penetration, macadam	May 15	86,345.51	20,015.92
	99A	Thomas	2.500	Bituminous, macadam	May 28	85,482.10	42,741.05
	107A	Worth	2.750	Kentucky rock, asphalt	do	100,000.00	50,000.00
	75	Gilmer	.537	Concrete and waterbound macadam	May 22	21,108.80	10,526.45
	90A	Cook	8.106	Paving	do	270,385.19	103,000.00
	10	Towns		Earth	May 20	[1] 20,195.87	[1] 10,117.36
	28	Paulding		do	May 15	[1] 18,945.86	[1] 9,580.88
Illinois	1–2	Dupage	.435	Concrete	May 24	[1] 12,906.42	[1] 13,437.10
	1–3	do		do	do	[2] 10,174.56	[2] 13,353.18
	1–6	Kane and Dekalb		do	do	[1] 21,016.56	[1] 18,251.20
	1–9	Ogle and Dekalb		do	do	[1] 14,683.77	[1] 22,123.11
	2–2	Iroquois		do	May 12	[1] 45,717.86	[1] 44,189.04
	2–7	do	.589	do	do	[1] 45,175.10	[1] 47,492.56
Indiana	20	Ripley	.977	do	May 10	49,690.37	19,540.00
Iowa	48	Humboldt	1.850	Brick, concrete, or gravel	May 15	88,588.35	28,127.50
	62	Blackhawk	17.170	Brick or concrete	do	818,376.51	343,400.00
	111	Kossuth	21.312	do	do	995,001.59	426,200.00
	115	Cerro Gordo	22.070	do	do	1,040,894.72	441,400.00
	23	Marshall	5.928	do	do	272,322.05	118,500.00
	30	Winnebago	7.450	Gravel	do	50,813.34	25,400.00
	43	O'Brien	22.500	Brick or concrete	do	1,063,248.45	450,000.00
	89	Polk	7.220	do	do	340,179.67	144,400.00
	109	Palo Alto	11.050	do	do	339,153.65	169,500.00
	114	Scott	17.114	do	do	913,901.12	340,000.00
	42	Wapello	10.500	Earth	do	90,646.27	45,300.00
	22	Linn	.009	Gravel and earth	do	[1] 207,496.85	[1] 136,032.18
	5	Buchanan	.040	Gravel and concrete	do	[1] 647,330.52	[1] 289,058.65
Kansas	3ABC	Barton	22.083	Brick and concrete	May 11	1,504,566.09	331,245.00
	33B	Bourbon	4.595	Bituminous macadam	May 12	149,355.83	68,925.00
	42	Meade	5.309	Earth	do	51,077.33	25,538.66
	49	Ottawa	5.484	Brick or concrete	do	358,569.84	81,250.00
	50	Bourbon	.520	Bituminous macadam	do	16,208.58	7,800.00
	43	Wilson	24.834	Gravel	May 19	579,561.86	147,500.00
Kentucky	16A	Warren	1.949	Rock asphalt macadam	May 12	49,999.84	24,999.92
	9A	Todd	4.274	Waterbound macadam	May 11	73,142.87	36,571.43
Louisiana	64	Concordia	8.980	Gravel with clay binder	May 20	153,898.54	76,949.27
	47	East Carroll	35.060	Gravel	May 28	412,455.01	206,227.50
Maine	5	Washington	5.182	do	May 11	84,255.27	42,127.63
	1	Sagadahoc		Bituminous macadam	do		[1] 13,194.65
Massachusetts	17	Essex	1.794	do	do	63,125.86	31,562.93
	18	Worcester	2.797	Concrete	do	117,690.10	55,940.00
	25	Middlesex	.597	do	do	82,641.35	38,389.77
	28B	Berkshire	2.690	do	do	109,772.85	53,800.00
	31	Essex	1.107	Bituminous macadam	do	45,544.87	22,140.00
Minnesota	84	St. Louis	1.130	Concrete	May 12	59,625.72	20,000.00
	75	Murray	17.700	Gravel	May 20	156,489.52	50,000.00
	113	Crow Wing	3.340	Concrete	May 18	110,967.50	31,860.30
	37	Hennepin	5.510	Asphaltic concrete	May 28	202,168.26	40,000.00
	112	Polk	1.356	Concrete	do	51,180.80	25,000.00
	11	Goodhue		Gravel	May 24	[1] 6,524.22	[1] 10,227.68
	81	Marshall		do	May 17	[1] 49,190.04	[1] 35,000.00
	3	Mille Lacs		do	May 12	[1] 42,508.98	[1] 34,000.00
Mississippi	80	Adams	3.600	do	May 11	49,648.34	24,824.17
	10	Lincoln		do	May 12	[1] 45,695.52	[1] 22,857.36
Missouri	43	Montgomery	8.241	Macadam	do	61,993.22	30,996.61
	56	Jasper	4.030	Concrete	do	103,555.66	51,777.83
	83	Jasper and Newton	9.440	do	do	244,242.04	122,121.02
	30	Morgan	11.077	Gravel	May 25	83,159.12	41,579.56
	14	Buchanan	10.710	Brick on concrete base, asphalt concrete, and concrete.	May 28	546,575.48	136,643.87
Montana	22	Ravalli	4.340	Gravel	May 6	25,215.20	12,607.60
	92A	Granite	1.136	Earth	May 25	48,646.51	22,720.00
Nebraska	85A	Valley	13.390	do	May 10	86,641.79	43,320.89
	68A	Hitchcock	4.460	do	do	62,583.56	31,291.78
	88A	Cuming	3.340	Sand gumbo	do	45,090.01	22,545.00
	103	Scotts Bluff		Bridge	do	150,083.71	75,041.85
	121A	Perkins	8.930	Earth and sand-clay	May 13	50,714.19	25,357.09
	125A	Brown	7.760	Earth	May 8	75,988.46	37,994.23
	42A	Custer and Loup	5.930	do	May 13	69,317.51	34,658.75
	54	Deuel	10.960	do	do	42,373.32	21,186.66
	79	Morrill	13.390	Earth and sand-clay	do	62,044.40	31,022.20
	104	Hall	3.013	Earth	do	11,791.10	5,895.55
	58A	Colfax	1.416	Concrete and earth	May 24	84,435.25	28,332.00
	7	Kearney, Adams, Clay, Nuckolls.		Earth	May 10	[1] 48,211.35	[1] 24,105.68
	50	Merrick and Nance		Earth and sand-clay	May 8	[1] 23,933.09	[1] 11,966.55
	78	Douglas		Earth	May 10	[1] 15,106.68	[1] 7,553.34
	100	do		do	May 8	[1] 10,373.89	[1] 5,186.95
	52	Phelps		Gravel clay	May 10	[1] 17,563.54	[1] 8,781.77
	40	Thayer		Earth	May 13	[1] 9,805.64	[1] 4,902.82
	75	do		do	May 10	[1] 20,528.99	[1] 10,264.50

[1] Modified agreements. Amounts given are increases over those in the original agreement. [2] Modified agreements. Increase. Revised statement.

PROJECT AGREEMENTS EXECUTED IN MAY, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
New Hampshire	88	Hillsborough	1.450	Gravel	May 4	$25,137.97	$12,568.98
	106	do	.379	do	May 6	8,363.30	4,181.65
	90	do	1.300	Modified asphalt	May 10	26,138.64	13,069.32
New Jersey	17A	Burlington	3.313	Concrete	May 19	266,322.13	66,260.00
	19	Mercer and Middlesex	1.440	do	do	122,382.37	28,800.00
	13	Salem and Gloucester	7.248	do	do	336,689.32	144,960.00
New Mexico	20	Lincoln	7.880	Gravel	May 12	109,173.39	54,586.69
New York	24	Herkimer	3.250	Reinforced concrete	May 28	114,470.00	57,235.00
North Carolina	60	Lenoir	7.880	Concrete	May 6	284,725.35	26,249.23
	45	Buncombe		do	May 15	[1] 143,078.27	[1] 71,539.14
	38	Rockingham		Topsoil	May 8	[1] 12,041.10	[1] 10,514.32
	18	Alexander		Sand clay	do		[1] 8,223.24
North Dakota	31	Lamoure		Gravel	May 14	[1] 3,883.19	[1] 1,941.59
	3	Williams		Earth	May 6	[2] 14,344.98	[2] 7,172.49
Ohio	136	Clermont	2.542	Bituminous or waterbound macadam	May 21	73,100.00	35,000.00
Oklahoma	9	Le Flore		Bridge	May 11	33,934.73	16,967.36
Oregon	17	Malheur	9.260	Earth	May 7	115,462.16	57,731.08
	22	Clatsop		Bridge	do	339,482.66	169,741.33
	24	Gilliam	14.950	Earth	do	231,035.31	115,517.65
	25	Sherman	14.810	do	do	226,836.77	113,418.38
	26	Klamath	8.960	Broken-stone macadam	do	144,315.93	72,157.96
	27	Columbia	10.870	Bituminous concrete	do	315,847.07	157,923.53
	31	Klamath	14.680	Gravel	May 25	170,535.25	85,267.62
	34	do	12.800	Broken stone and gravel macadam	do	127,138.99	63,569.49
Pennsylvania	57	Clearfield	2.448	Reinforced concrete	May 11	142,076.55	48,960.00
	68	York	6.052	do	do	319,409.42	121,040.00
	69	do	4.878	do	do	280,574.39	97,560.00
	70	Adams	5.594	do	do	333,634.78	111,880.00
Rhode Island	6	Providence	2.920	Bituminous concrete	May 12	121,331.54	58,400.00
	7	Newport	2.560	Bituminous macadam	do	113,019.50	51,200.00
South Carolina	10A	Lancaster	15.447	Gravel	do	147,729.27	56,810.77
	82 A B & C	Union	16.785	Topsoil	May 11	110,289.86	55,144.93
	5	Chesterfield		Gravel	May 18	[2] 7,633.94	[2] 3,816.97
	20	Cherokee		Topsoil	May 3	[1] 19,557.40	[1] 9,777.70
South Dakota	9	Brown		Gravel	May 21	[1] 10,940.53	[1] 5,470.26
Tennessee	21	Carroll	12.270	Chert	May 12	238,279.39	119,139.69
	6	Washington		Waterbound macadam	May 28	[1] 113,039.76	[1] 56,519.88
	2	Hamilton		do	May 13	[1] 31,534.09	[1] 15,767.05
Texas	56B	Jefferson	2.350	Gravel and rock asphalt	May 15	70,200.00	35,100.00
	106	Brazoria	9.440	Oyster mud shell	May 11	156,671.44	39,169.89
	116	Tom Green	26.540	Waterbound macadam	May 15	332,856.32	100,000.00
	51	Madison	20.260	Earth	do	113,977.11	43,494.28
	109	Wood	21.690	Gravel	do	168,214.84	63,500.00
	101	Bowie		do	May 18	[1] 5,837.86	[1] 2,698.91
	79	Caldwell		do	do	[1] 2,663.65	[1] 1,010.13
	49	Nolan	11.840	do	do	[3] 65,191.04	[3] 32,595.52
	52	Callahan		Gravel and waterbound macadam	May 15	[4] 107,834.44	[4] 25,000.00
	4	Travis		Surface-treated gravel	do	[1] 36,529.36	[1] 10,000.00
	66	Comal		Gravel, surface treated	do	[2] 8,049.00	[2] 4,024.50
Utah	34	Utah	5.740	Concrete	May 11	221,299.66	110,649.83
	11	Iron	33.300	Gravel	do	313,965.13	156,982.56
	5	Grand	2.460	Earth	May 5	[1] 77,174.16	[1] 38,587.08
Virginia	56	Tazewell	5.505	Gravel	May 8	66,421.78	33,210.88
	74	Princess Anne	10.977	Concrete and reinforced concrete	do	408,648.92	204,324.46
	19	Fauquier		Waterbound macadam	May 18	[1] 16,557.70	[1] 8,278.85
	51	Loudoun		do	do	[1] 6,467.40	[1] 3,233.70
Washington	49	King	4.840	Concrete	Apr. 26	151,219.64	75,609.82
West Virginia	61A	Summers	1.816	Earth	May 17	38,000.00	19,000.00
	69	Braxton	6.540	do	May 28	79,875.00	39,937.50
	50A	Clay	2.950	do	do	62,600.00	31,300.00
	3A	Pendleton		do	May 11	[1] 4,234.89	[1] 2,472.10
Wisconsin	99	Douglas and Washburn		Gravel			[1] 3,039.39
	13	Park		Earth	May 12	[1] 26,572.58	[1] 8,623.79
	76	Portage	6.400	Gravel	do	[3] 32,292.92	[3] 10,764.30

[1] Modified agreements. Amounts given are increases over those in the original agreement.
[2] Modified agreements. Inerease. Revised statement.
[3] Canceled.
[4] Modified agreements. Amounts given are reductions from those in the original agreement.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
249. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States, 1914. A Summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
463. Earth, Sand-Clay, and Gravel Roads.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
691. Typical Specifications for Bituminous Road Materials.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and Classification of Rocks for Road Building, Including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
77. Experimental Roads in the Vicinity of Washington, D. C.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918.
Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D– 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D– 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D– 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D– 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D– 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 5, D–12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 10, No. 7, D–13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D–15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D–16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

CLEMSON COLLEGE LIBRARY

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 27 WASHINGTON, D. C. JULY, 1920

A STRETCH OF NEW JERSEY FEDERAL-AID PROJECT NO. 14

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Highway Administration and Road Conditions in France 3

Suggestions for Improvement of the Deval Abrasion Test for Rock . . 9
F. H. Jackson.

The Characteristics of Steam Distilled Petroleum Residuals 13
B. A. Anderton.

Good Progress in Impact Tests 18

Photographic Hints for Engineers 19
John K. Hillers, jr.

Last Apportionment of Federal Aid 22

Manufacture and Use of Laboratory Diamond Drills 23
F. H. Schloer.

Federal-Aid Allowances 25

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer

HIGHWAY ADMINISTRATION AND ROAD CONDITIONS IN FRANCE

IN OCTOBER, 1919, the Department of State, at the instance of the transportation section of the Council of National Defense, transmitted a questionnaire to American consuls regarding highways and highway transport conditions throughout the world.

To date replies have been received from about 90 consular districts. The data is voluminous and much of it is of considerable value. The questions which were asked, and to which replies are being received in one form or another were as follows:

1. Total number of miles of road in the country, outside of incorporated cities and towns.
2. Classification as to character of improvement and type of roads.
3. Classification according to administration.
4. Cost of construction per mile, also per square yard, under the various stated classifications.
5. Cost of ordinary maintenance per mile and per square yard per annum under the various classifications given, excluding resurfacing and extraordinary repairs.
6. Annual amount of Government expenditure for construction, for ordinary maintenance, and for extraordinary repairs.
7. Amount and character of local contribution of each administrative class and nature of apportionment and securement.
8. Nature of governmental direction of construction and maintenance, including jurisdiction and supervision, describing administration and organization.
9. Comparison and relation of units of government in other countries for purpose of comparison with the United States, namely, the correlation between our States, counties, and road districts and our Federal Government.
10. Whether or not any tax is levied on abutting land; if a tax, the nature, amount, and method of collection.
11. Where obtainable, secure concrete tables showing cost per ton-mile of highway transportation, both before and after road improvement, the desideratum being to ascertain the saving in hauling freight on highways on the basis of the ton-mile because of the road improvement.
12. Cost of hauling produce or freight per ton-mile, giving data on which such estimates are formed, including tonnage, general nature of freight, kind of vehicles used, whether cost of vehicles and power taken into calculation; if so, what percentage of cost charged for annual depreciation. Maximum load in each case, number of individuals figured in making up estimates, and wages or cost of labor in the activity, and average length of haul on which the calculation is made.
13. Whether good road or highway construction has to any degree been substituted for railway branch lines or feeders to railroads; whether railroads, where under private ownership, contribute in any way to tax or contribution, directly or indirectly, toward road construction.
14. Average length of highway haul for produce or other commodities from point of origin to destination, excluding rail and water haul.
15. National and local sources and methods of raising revenue for highway construction and maintenance.
16. Explain system of estimates, accounting, and cost keeping, tracing road funds from origin to final audit and approval, submitting such forms and reports as are customarily used, also table of salaries and administrative personnel.
17. Any concrete information obtainable where highway improvements have increased the value of abutting and contiguous property and the percentage of such increase in value.
18. Number of highway transportation units in operation and type, specifying separately motor passenger and freight vehicles, and other means of travel such as horse, mule, or bullock drawn wagons.
19. Plans for future highway construction and type of road to be constructed.
20. General forecast as to possibilities of future development of country through means of improved highways transportation.

On account of the value of much of the material which is being received, the Bureau of Public Roads will publish the most important data in PUBLIC ROADS in serial form.

INFORMATION FROM FRANCE.

France has been selected as the subject of the first installment because of its preeminence in matters of road construction. Subsequent issues will publish the data on the British Isles, Canada, Switzerland, Sweden, and other countries. The greater nations will be treated as fully as the data at hand will permit; the information received from the lesser countries will be abstracted and published in condensed form. Those who are interested to obtain more information than is contained in the published data may do so by applying either to the Bureau of Public Roads or to the Council of National Defense where the original reports are on file.

The French information published in this installment has been obtained from the consular offices at Lyon and St. Etienne, which, together, are responsible for 20 of the 87 departments, as follows: Ain, Belfort (Territory), Drôme, Haute-Saône, Haute-Savoie, Isere, Jura, Rhône, Savoie, Saône-et-Loire, Allier, Côte-d'Or, Doubs, Ardeche, Aveyron, Cantal, Haute-Loire, Lozere, Loire, and Puy-de-Dome.

It is, therefore, in no sense complete, but it is sufficiently inclusive to convey a knowledge of road con-

ditions, and methods of administration in our sister Republic far more exact than the average American highway engineer has heretofore possessed.

The French units of government corresponding to the American units are as follows:

The State corresponding to our Federal Government.

The Departments corresponding to our States.

The arrondissments corresponding to our counties.

The communes corresponding to our townships.

All roads are classified as follows:

Routes nationales, or National highways, which are under the administration of the National Government.

Routes departementales, or State highways, which are under the direction of the Departments.

Chemins de grande communication, or main lines of communication, and chemins d'intérét commun, or roads of general interest, correspond to our State-aid roads and are built by the communes, supplemented by grants from the Departments.

Chemins vicinaux ordinaires, or ordinary country roads, are almost entirely at the expense of the communes, with occasional aid from the Federal Government.

THE NATIONAL HIGHWAYS.

The routes nationales, or national highways, are constructed and maintained in condition by the ministry of public works, under which in direct charge is the Service des Ponts et Chaussées, or the department of roads and bridges. Funds for construction and maintenance of roads of this class are derived solely from national sources, except that in certain cases of special repairs, as when it is necessary to tar the roads, a special tax is levied on the beneficiaries by the improvement (either 50 per cent of the cost or in proportion to the advantages deemed to accrue).

Plans and specifications are prepared by the department of roads and bridges, and the construction and maintenance of the roads are executed under the supervision of the Parisian Department.

Basing the estimate on the returns from nine Departments, which report the mileage of the roads of the several classes, the routes nationales constitute approximately 6 per cent of the total mileage of roads in the country.

Gravel and macadam are the prevailing types of surfaces, the roads of heaviest traffic being paved with stone blocks. Owing to the general increase in the weight and volume of traffic in all Departments, there is a tendency to replace madacam with more durable pavements. Asphalt will be used on certain routes, and where it is not sufficient paving stones will be used to resist the traffic.

The width of the national highways varies from about 19 feet to 29 feet including sideways or shoulders. Their thickness is difficult to determine, owing to the fact that they have been built up through successive applications of stone decade after decade. Many of them undoubtedly are upward of 20 inches in thickness. One road of this class, route national 23, which was resurfaced by the American Army, is reported by the officer in charge of the work to have the following composition, totaling 42 inches in thickness: A surface course of 3 inches of limestone, underlain successively by 4 inches of trap rock, 7 inches of coarse gravel, 18 inches of crushed granite in 3 or 4 inch fragments and 10 inches of Telford base. In resurfacing it is common to add from 3 to 4 inches of new stone.

The average cost of construction of all national highways before the war was 45,000 francs per kilometer, or about $13,685.75 per mile.[1] As the prewar costs of nearly all commodities and services have since been increased from 250 to 300 per cent, the cost of such construction is now probably from $32,000 to $40,000 per mile.

The 1920 budget estimates the cost of maintaining the roads of this class at 1,800 francs per kilometer, or about $550 per mile.

STATE HIGHWAYS.

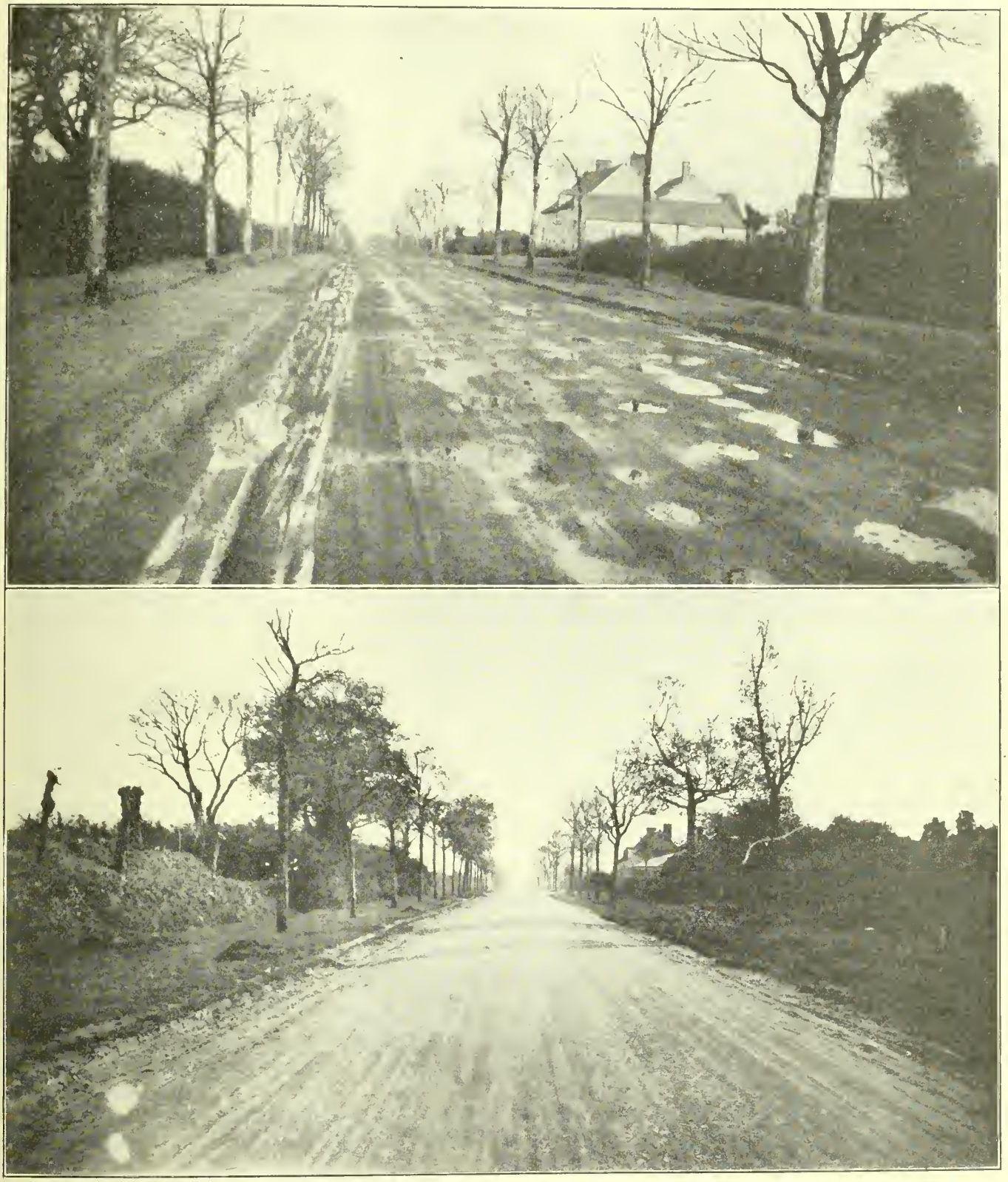
The routes départementales, or State highways, constitute about 4½ per cent of the entire mileage of roads. They are paid for entirely from the funds of the Departments. The departmental commission appoints the personnel of the road service, a corps of State engineers known as agents-voyers, which consists of a chief road surveyor, two district road surveyors, and from 20 to 40 local road surveyors for each of the 87 departments. This corps assumes control over the preparation of the plans, and the execution of surveys, construction, and maintenance for the departmental roads. The Federal Government intervenes in the construction only when it is necessary to take possession of private property for the public use or to approve laws dealing with the alignment of buildings along the thoroughfares.

In type of construction the departmental roads are similar to the routes nationales. In width they average from 5 to 6 meters, i. e., from about 16 to 20 feet. Their thickness is usually considerably less than that of the national highways, conforming in this respect more closely to the dimensions of American roads. In the Department of Haute-Savoie, for example, the specified minimum thickness is 0.20 meter or 7.84 inches.

Before the war the Departments were paying in the neighborhood of $8,000 per mile for roads of this class. It is estimated that this cost under present conditions will be tripled. The cost of maintenance, which in the prewar days was about $300 per mile, is expected to amount to $500 or $600 per mile this year.

In many of the Departments all roads have lately been reclassified, and the departmental classification

[1] The rate of exchange in this conversion as in all others in this article is assumed to be 1 franc=19.3 cents.



TOP, THE CONDITION OF ROUTE NATIONALE 23, FRANCE, AFTER THE ARMISTICE. BOTTOM, THE SAME ROAD AFTER IT WAS RESURFACED BY THE ENGINEERS OF THE AMERICAN ARMY.

has been abandoned. Roads formerly in this class have been denominated main lines of communication and will be maintained hereafter by joint funds of the Departments and the communes.

MAIN HIGHWAYS AND COMMUNAL ROADS.

Roads of these classes, comprising the chemins de grande communication, the chemins d'intérêt commun, and the chemins vicinaux ordinaires constitute the large majority, approximately 90 per cent of the total of 417,500 miles of road in France.

As the national roads are designed to connect the principal cities of the Republic, so the main lines of communication connect the lesser cities of only local importance.

The road surveyors, or agents-voyers, have charge of the construction and maintenance of these roads. In general, the costs are defrayed from the funds of the communes supplemented by grants from the Department, the latter paying as much as 55 per cent. The communes interested meet their quotas from their ordinary sources of revenue, or if this is insufficient, by a special small tax of a few centimes levied upon all whose names are enrolled on the direct tax list. In addition to the monetary taxes, the communes also exact three days' labor per year of every able-bodied male inhabitant between the ages of 18 and 60, or in lieu of the labor a cash contribution at a regular rate per day. If a man is the head of a family he is responsible for the labor or prestation of every able-bodied male member or employee of his family as well as for every beast of burden and every vehicle which he owns, for these also are subject to the three days' prestation. Public-spirited citizens often contribute to the construction of the roads by the free transfer of their lands for that purpose. In such cases, the value of such lands is deducted from the amount of the contribution due from the town.

SPECIAL TAX ON HEAVY VEHICLES.

One of the taxes levied by the French which will be of special interest to highway engineers in America is the special tax which is levied upon large industries whose business is such as to impose unusual wear and tear on the roads by their heavy traffic. This tax is known as the industrial subsidy.

No special taxes are levied upon abutting property. In general, roads are constructed, not for the purpose of increasing property values, but to unite the towns and villages and facilitate their mutual intercourse and commercial relations. The Frenchman concedes that the creation of new roads adds to the value of the property traversed, but such increase is too variable, he thinks, to ascertain with accuracy. Moreover, it is much less important than one would suppose on account of the great number of roads already existing. It is the exception where the construction of a new oad increases the value of abutting or contiguous property to any notable extent. If the owners of property wish to increase the value of their lands unprovided with roads, they construct them at their own expense.

While the main routes are not departmental roads, but rather are supposed to belong to the communes through which they pass, the fact that they extend over several towns gives them an intercommunal value which justifies placing them under departmental administration. The closest American counterpart of the roads of this class are the State-aid roads of our States. For the reason above stated the roads of this class are placed under the administration of the Department prefect or governor, subject to the payment by the towns interested of the annual quota for their maintenance and repair. Estimates relative to the funds required for construction, maintenance, and repair are prepared annually by the Department road surveyors, and such estimates for the coming year are incorporated in the primitive budget established by the general council of the Department in its second session. At the first session in the year for which the estimates have been made the council votes a supplementary budget to which are added the funds left over from the preceding quarter and the new receipts. Expenditures for construction are approved by the prefect and paid by the treasurer of the Department.

The departmental accounts are settled annually, but the road accounts extend over a period of 14 months, at the end of which the treasurer renders his accounts and vouchers showing the receipts and expenditures for the construction and maintenance of the roads to the cour des comptes at Paris which audits the accounts of the treasurers of all the Departments.

The roads of general interest and the ordinary country roads which are comprised in the last two classifications are solely of communal value and concern, except that where the commune requires aid in keeping its roads in shape, it may receive aid from the Federal Government, or under rare conditions from the Department. Any balance which remains in the funds derived from the regular and special taxes after the share of the commune in the cost of the main highways has been met is devoted to the construction and repair of the roads of lesser importance. There is, moreover, a provision allowing an extra day of prestation to be devoted to these classes of roads.

The agents-voyers do not concern themselves with the roads of this class; they are administered entirely by the mayors of the towns. On a smaller scale the machinery established to account for and expend the town road funds is similar to that which has already been described for the Department, the accounts of the town treasurer being verified annually by the council of the prefecture if the ordinary resources of the town do not reach the sum of 30,000 francs, and by the cour des comptes, if they exceed that sum.

Like nearly all roads in France the main and lesser communal roads are generally surfaced with macadam, and are from 4 to 5 meters in width, with a minimum thickness of about 6 inches. On the main roads the grades compare favorably with those of the national and departmental highways, and on the lesser roads the grades do not generally exceed 8 per cent, though occasionally an aclivity of 10 or 12 per cent is found, in which case the road becomes little better than a mule path, its outside width not exceeding 3 meters or about 10 feet.

WAR HALTS SYSTEMATIC MAINTENANCE.

The famous maintenance system to which America and the world have turned for a pattern of all that is best in road up-keep was totally disrupted by the war. Almost no attention could be given to the roads from 1915 to the end of 1918, except in the war areas. In such areas the effort was to keep the roads passable for army traffic, not, as in other days, to maintain them in perfect condition. Such neglect has been attended by its natural result. The roads, especially the national and departmental roads and the main lines of communication which have borne the brunt of the war traffic, are in a serious condition of disrepair. This is especially true in the neighborhood of army camps and in the environs of large industrial centers.

Many of the Departments are now setting about to repair the damage which has been done and it is hoped that by 1923 the condition will be greatly ameliorated. The task is made more difficult than it was before the war by reason of the fact that while the traffic of heavy units has fallen off since the war, it has not, by any means, dropped to the prewar density. Heavy motor camions are now to be seen in far greater numbers than in former years, and the deterioration of the roads is expected to be more rapid than formerly.

LABOR AND MATERIAL LACKING.

Necessary as it is that the work of rehabilitation be prosecuted with the utmost expedition, the Departments are faced with the fact that the desired speed will not be possible to attain. Many of the cantonniers are not yet released from the military service. Labor to take their places and to augment the usual forces is scarce and expensive. Supplies of material have not been obtainable except at great difficulty, particularly because of the lack of enough railway cars. Before the war, machinery was not used in the construction of the French roads in any manner approaching the use which is made of it in America and England. Now it is recognized as an essential to replace laborers and animals by mechanical devices. Already a number of the departmental councils are in touch with leading French, British, and American manufacturers looking to the purchase of equipment and machinery with which to carry on the war against the forces of road destruction. Indeed the recital of the difficulties which, for the French highway engineer, have followed in the train of the war, and the plans which are being made for the solution of the problems sounds to an American like a description of the situation which confronts his own country. The problems of the two countries seem to be identical; the general lines of the solutions which are being worked out are similar; and it would seem that great benefit would result to the engineers of the two Republics from a more intimate interchange of experiences.

PAY OF ENGINEERS AND LABORERS.

Engineers in public service in the United States will no doubt be interested in the scale of salaries paid to their brothers in France, listed in the following table, which applies to the Department of the Loire.

	Salary per year.
Agent-voyer en chef (State highway engineer)	$2,120–$2,700
Agent-voyer d'arrondissement (district engineer)	1,740– 2,030
Agent-voyer cantonaux (resident engineer)	1,060– 1,740
Employés expéditionnaires (assistant engineers)	870– 1,350
Dames dactylographes (stenographers)	695– 1,000

The salaries seem somewhat low in American eyes, but the numerous perquisities and allowances add to them materially, particularly if the engineer is so fortunate as to have a family. Thus there is an annual allowance for traveling expenses which varies from $150 to $450. The annual quarters allowance is only from $20 to $60. But for his family the engineer receives a substantial gratuity for each child under 16 years of age. For each of the first two he receives $63 per month. For the third child the allowance is $87 per month, and if he is blessed with a more numerous family he receives $93 per month for the fourth and each younger child.

Wages of laborers have not yet reached the high levels attained in the United States, but they have greatly increased since 1905. In that year road foremen in the Department of Saone-et-Loire were paid only $16 per month, and laborers received $12 for a month's work. The rates reported from the Department of the Loire for 1920 are $55 to $61 per month for road foremen and $46 to $55 per month for laborers. In addition the laboring forces also receive allowances similar to those received by the engineers. If he is stationed in a large industrial city the chief cantonier receives a monthly addition to his pay which varies from $3 to $7.30; laborers similarly situated receive from $2 to $6 monthly. The chief cantonier receives the equivalent of about $24 per year for his bicycle which he uses in making inspections, and if he makes a trip exceeding 20 kilometers on foot or 30 kilometers by bicycle, he is allowed 35 cents additional. His lodging is paid for at the rate of $1 a night, and in addition to all these, foremen and laborers alike are granted the same gratuities for family maintenance

which are extended to the engineers; in their case, however, only for children under 13 years of age.

THE USE OF ROADS.

The reports indicate that the maximum haul for produce or other commodities from the point of origin to destination, excluding rail and water haul, is about 40 kilometers (18.5 miles). This is the maximum round-trip distance which may be covered by an ordinary team of horses in one day; the average haul by road is somewhat less. For distances exceeding 18 miles the railroad is used where there is one. However, since the railway strike a large number of industries in the larger centers transport their commodities by motor trucks, in which case the haul is reported as much greater, but no definite limits are assigned.

In some small towns and villages short roads have been constructed leading to the railway stations situated near the towns, and in such cases it is the railway company which pays the cost of constructing such roads.

The use of motor trucks has greatly increased since the transport crisis, and it is reported that the companies engaged in moving freight charge from 21 to 26 cents per kilometric ton per kilometer, which is from 31 to 38 cents per ton-mile, approximately. No estimate as to the actual cost to the companies was obtainable, nor as to the percentage of profit contained in their public prices. More indicative, perhaps, of real costs is the estimate given by the municipal road service of the Department of Rhone. No profit being figured in the costs of operating and care of the municipal trucks, the actual cost to the municipality is stated as averaging 3 francs per 4½ kilometric tons per kilometer, which is about 20 cents per ton-mile.

MARKING THE HIGHWAYS.

The increased use of the roads by motor traffic during and since the war and the prospective influx of tourist traffic has directed attention to the importance of a revision of the system of highway marking.

The small iron signs which have heretofore been used have been suitable for low-speed traffic but will not do for a rapidly moving traffic, as the inscriptions are so small that they can not be read while cars are in motion, and at night they are often without the radius of automobile headlights.

During the war the French and allied armies had recourse to striking signs with large letter inscriptions, painted on wood or canvas, or, whenever possible, on the walls of houses. These were placed at a proper height to be seen by drivers without difficulty by day or night. The direct result has been that the French Ministry of Public Works has decided to carry out the ideas developed through the war traffic: (1) By indicating noteworthy places, such as the names of towns, or dangerous places, and (2) by denoting the distance and direction to other places of importance.

A circular issued in August, 1919, by the ministry and addressed to all prefects of the departments, requires that the names of villages must be conspicuously posted, on a post or the wall of a building, as far as possible, perpendicular to the axis of the road and on its right.

A standardization of danger signals will result from the decision to use only the four signals adopted by the International Conference relating to automobile traffic held on October 11, 1909. The four signs indicate inclines, turns, road crossings, and railroad crossings, respectively, and they are to be placed at about 275 yards from the danger point unless special conditions prevent. They are to be perpendicular to the road and on the right of the direction followed.

Direction signs will be placed at the entrance to and exit from all hamlets, as well as at branch and cross roads. At road intersections there is to be a different signboard for each direction, containing only the following information: (*a*) The name of the first place or village in the direction indicated, and (*b*) the name of the first important town in that direction. The latter name will be identical on successive posts until the town in question is reached. Beside each name will be the distance in kilometers. The inscriptions are to be headed with an arrow and an abbreviation indicating the class of the road. All signs are to be placed so that they are within the radius of the lights of vehicles, and 6 feet 6 inches above the road if they are in a place where there is much pedestrian traffic, and 6 feet 3 inches high at the most if on a wall. The latter placing is recommended.

The inscriptions are to be white on a dark-blue background, with the lettering at least 5.9 inches in height, except for danger signals. Numerals will be a little smaller than letters. Iron, varnished sheet iron, or wooden signs are authorized. Enamel signs are not recommended, as they deteriorate too easily and are difficult to repair. Legislation is in preparation enabling the painting of signs on walls adjoining the roads, notwithstanding the opposition of the owner.

In carrying out the arrangements for the placing of these signs care is to be exercised to safeguard good appearance; the signs are to be looked after, so that the inscription will always be legible, and old-style signs are to be suppressed if they conflict with the new ones. It is hoped that the entire program of marking the roads of the Nation will be completed by December 31, 1921.

SUGGESTIONS FOR IMPROVEMENT OF THE DEVAL ABRASION TEST FOR ROCK.[1]

By F. H. JACKSON, Senior Assistant Testing Engineer, Bureau of Public Roads.

THIS Deval abrasion test is probably the best known and most widely used of the methods which have been developed for testing the quality of road-building rock. It has been in continuous use in this country for over 20 years and, in general, has been considered satisfactory for the purpose for which it was designed; that is, to measure the relative resistance of rock to wear or abrasion. In spite of this fact, however, it must be confessed that the method is weak in at least two particulars. In the first place, experiments made recently have indicated the possibility of a considerable error in results obtained due to variations in laboratory manipulation. For instance, Mattimore, in 1917, reported[2] a series of results in which 10 tests on a sample of dolomite made in the same laboratory and by the same operator but on different days showed a maximum variation in percentage of wear of 0.9 per cent. A corresponding series of tests on syenite showed a maximum variation of 1.3 per cent. In the same year Reinecke and Clark[3] in a paper before the society reported a maximum variation of 0.6 per cent on 17 duplicate sets of limestone, and a corresponding maximum variation of 0.3 per cent on 7 duplicate sets of igneous rock. In both of the cases cited, care was exercised to insure, as nearly as possible, the use of identical material in all of the check tests. The variations noted are therefore assumed to be due to laboratory manipulation alone.

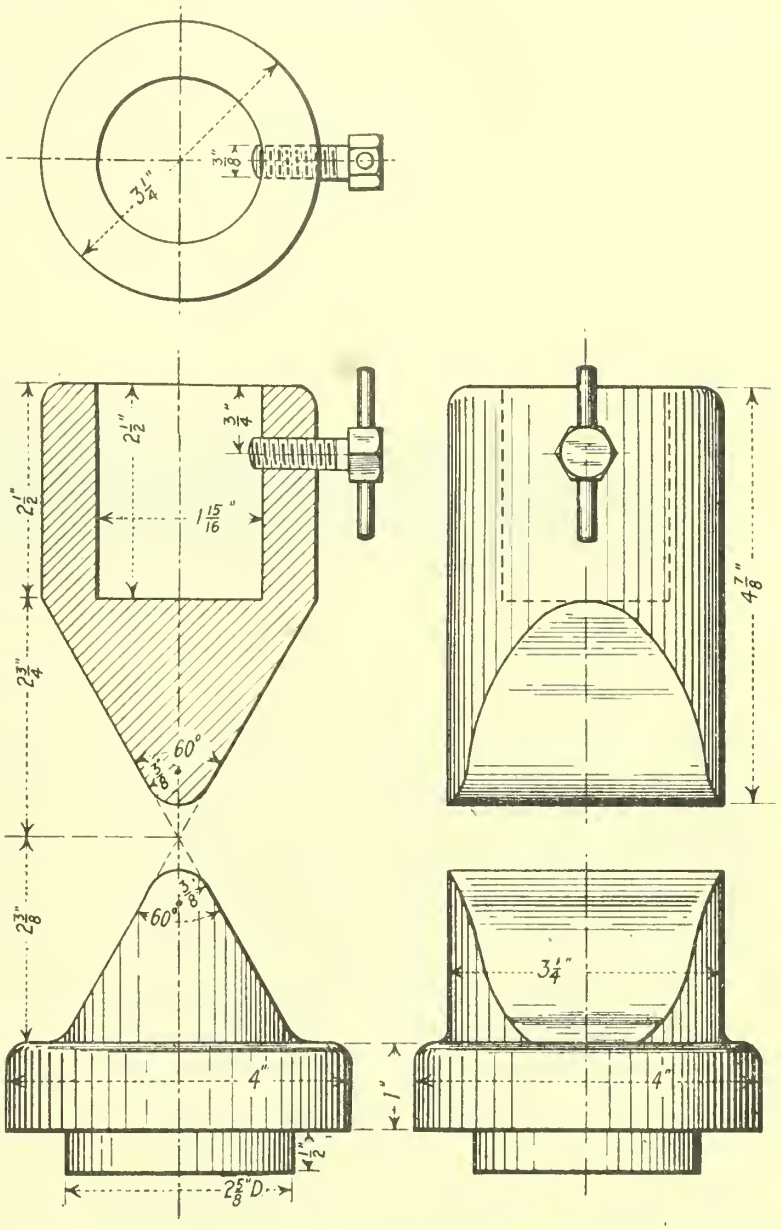


FIG. 1.—KNIFE EDGES USED ON MACHINE FOR PREPARATION OF SAMPLES FOR ABRASION TEST.

Results of tests made by the author along the same line are given in Table I. The results shown in the table were obtained from time to time in the course of the routine work of the laboratory of the Bureau of Public Roads and extended over a period of a year or more. No effort was made to specially prepare any of the samples. They were, however, all prepared by the same operator—an experienced man who has been engaged in this work for the past 18 years. These results indicate clearly the degree of accuracy which may be expected in a given laboratory and under average normal conditions. It will be noted that the average maximum deviation for the four types examined amounts to approximately 0.8 per cent. This would correspond, in the case of granite, trap, or other hard rock having, for instance, an average percentage of wear of 3, to a possible variation of from 12 to 16 in French coefficient of wear, or 4 points. This is rather a serious error and calls for a greater tolerance in interpreting the results of tests than we have been in the habit of considering necessary. The principal reason for the discrepancies noted is the practical impos-

[1] Paper read at the annual meeting of the American Society for Testing Materials, Asbury Park, N. J., June 22-25, 1920.
[2] Proceedings, Am. Soc. Test. Mats., Vol. XVIII, Part II, p. 415 (1918).
[3] Ibid., p. 398.

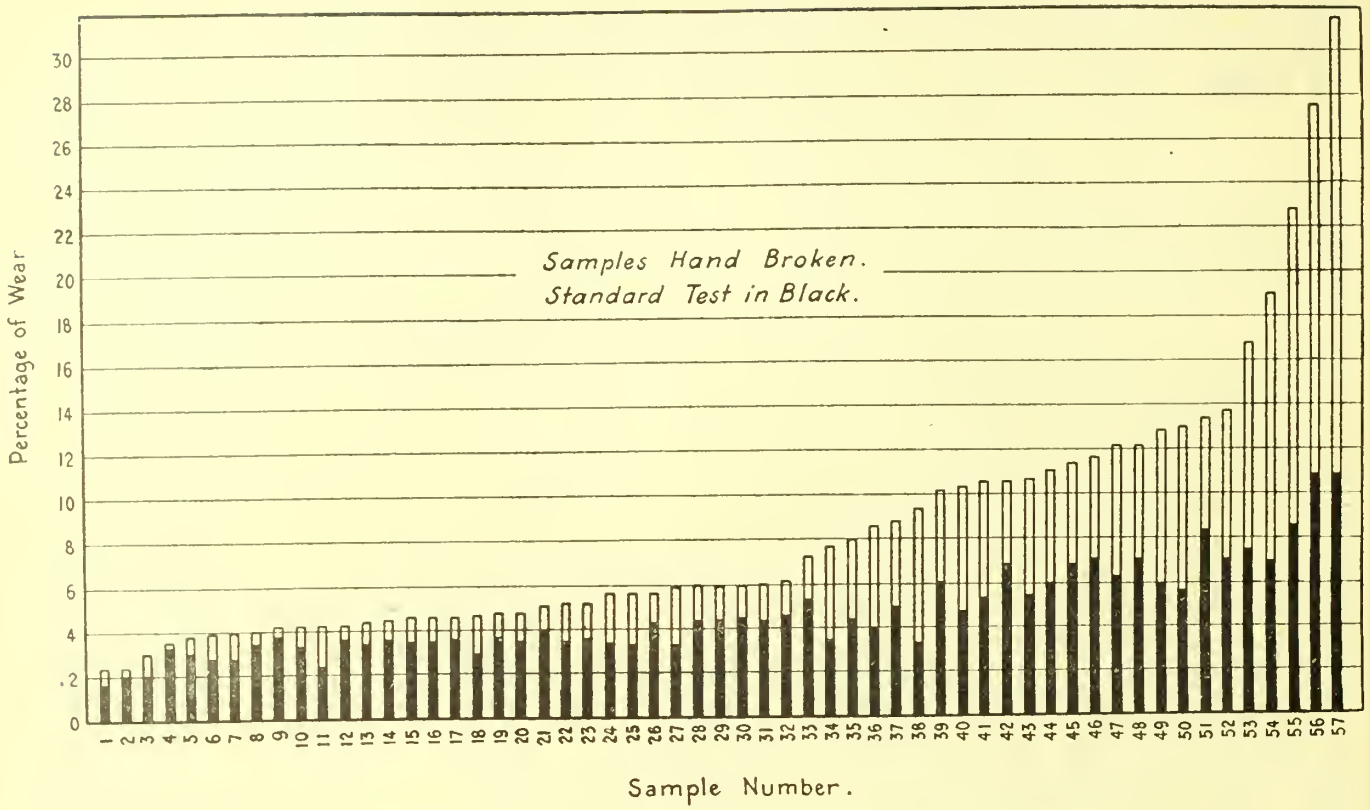


FIG. 2.—DIAGRAM SHOWING COMPARATIVE RANGE IN PERCENTAGE OF WEAR OF ROCK TESTED IN THE STANDARD AND SLOTTED ABRASION CYLINDERS.

sibility of securing by the ordinary method of hand-breaking a test sample consisting of 50 pieces all of the same size and shape. It is, of course, obvious that variations in either respect will affect the results obtained, particularly if the stone be unusually soft or brittle. The present standard method requires that a sample of rock for the abrasion test shall weigh within 10 g. of 5,000 g. and shall be composed of 50 pieces of freshly broken stone of as nearly the same size as possible. While no reference is made to the shape of the pieces, the assumption has always been that cubical fragments should be prepared. It has been the author's experience that such a sample is extremely difficult to prepare in the ordinary manner in a reasonable length of time. As a matter of fact, it may be doubted whether it is even approximated in the majority of laboratories.

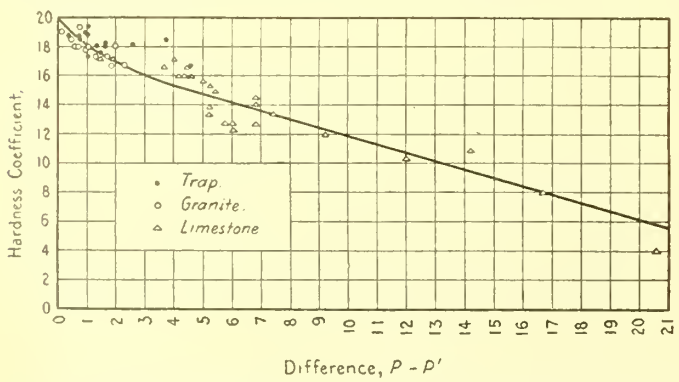


FIG. 3.—RELATION BETWEEN COEFFICIENT OF HARDNESS AND DIFFERENCE BETWEEN THE PERCENTAGE OF WEAR AS DETERMINED BY THE STANDARD METHOD AND WITH THE SLOTTED CYLINDER.

TABLE I.—*Comparative results of abrasion tests using standard and proposed methods.*

Test No.	Type of rock.	Percentage of wear by standard method.					Percentage of wear by proposed method.				
		Individual results.			Average.	Maximum deviation.	Individual results.			Average.	Maximum deviation.
1	Granite....	4.0	4.3	4.6	4.3	0.6	6.0	5.8	5.7	5.9	0.3
2	.....do.....	5.0	4.4	4.6	4.7	0.6	6.0	5.9	6.1	6.0	0.2
3	.....do.....	3.0	3.3	2.9	3.1	0.4	3.9	4.1	4.0	4.0	0.3
4	Trap.....	2.0	2.7	2.5	2.4	0.7	3.0	3.2	3.0	3.1	0.2
5	.....do.....	2.9	2.5	2.6	2.7	0.4	4.0	4.1	4.3	4.2	0.3
6	Limestone.	5.9	6.3	6.8	6.3	0.9	12.0	12.3	12.4	12.2	0.4
7	.....do.....	9.3	10.8	10.6	10.2	1.5	29.4	29.0	29.6	29.4	0.6
8	Sandstone.	5.8	6.7	7.0	6.5	1.2	13.1	13.0	13.3	13.2	0.3
	Average.	.....	.....	.....	.....	0.8	.....	.....	.....	.....	0.3

USE OF FORCING PRESS.

Appreciating the need of a more rapid as well as accurate method of preparing samples, the laboratory of the Bureau of Public Roads has been for some time experimenting with a forcing press equipped with suitable knife edges for breaking stone. It was first used by the laboratory in the preparation of granite paving block samples for test because it was found that the variations obtained when specimens were hand-broken were so great that the results were of little value. It has a capacity of 20,000 pounds,

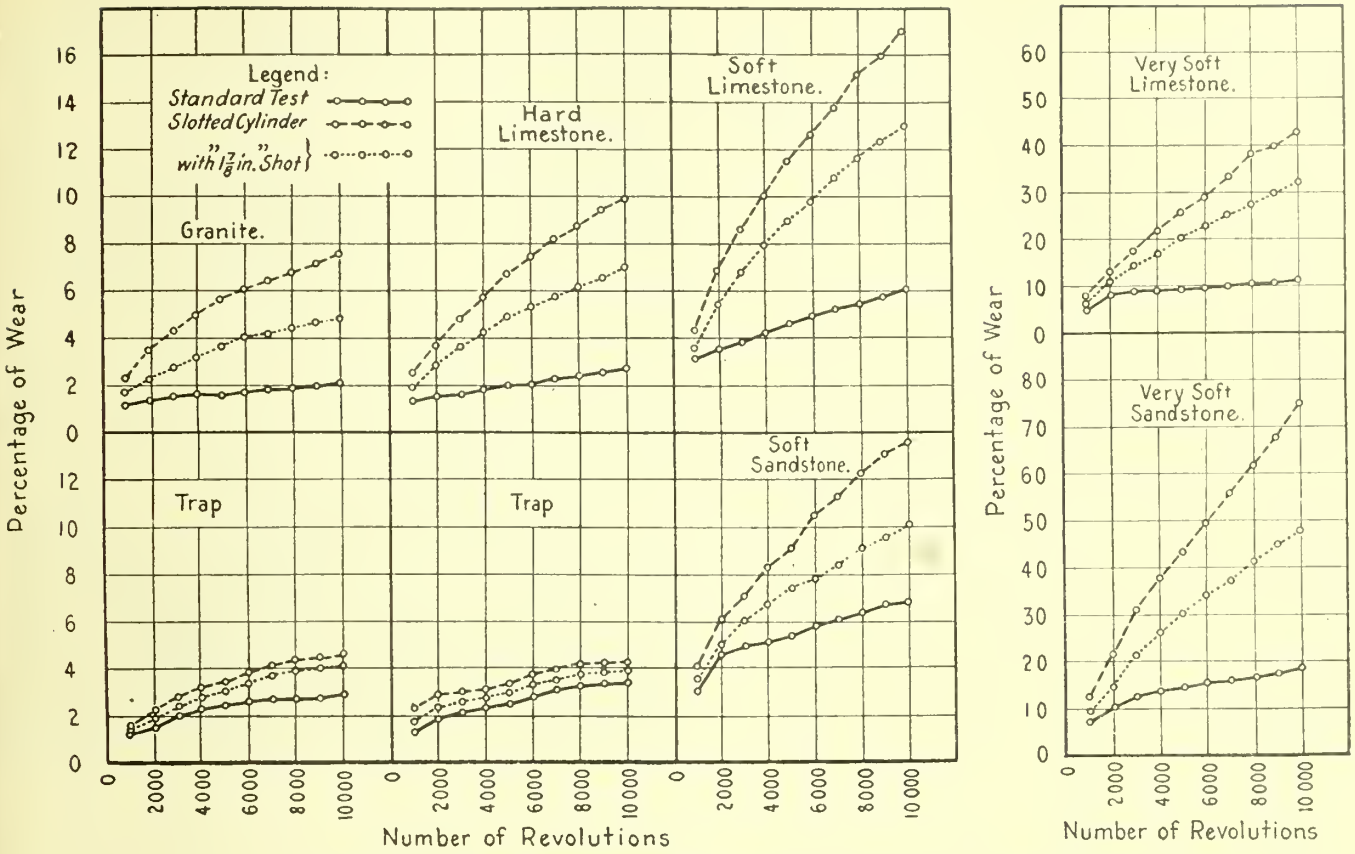


FIG. 4.—CURVE SHOWING THE RELATION BETWEEN PERCENTAGE OF WEAR AND DURATION OF TEST.

which is sufficient to break an ordinary standard-size granite block. By the use of this machine, small cubical fragments of the size desired may be prepared conveniently from practically all types of rock with the exception of some traps and the very highly foliated or laminated varieties, such as gneiss and schist. With these types it is always a question of doing the best possible with the material in hand. A standard sample prepared in the above manner will consist of 50 pieces, approximately cubical in shape, each of which should weigh from 85 to 115 grams. Results of tests on samples of different types of rock prepared in this manner and compared to tests on the same materials prepared in the usual way are shown in Table I.

The Deval test has been criticized also from another point of view. In a paper presented at the 1918 annual meeting of the American Society for Testing Materials, Scofield[4] called attention to the action of the so-called "dust cushion" on the inside of the abrasion cylinder. He showed that in eliminating this cushion by removing the dust of abrasion during the test, a much greater range in values could be obtained, especially among the softer rock types. Other investigators working along the same line had independently reached the same conclusion. Indeed, the present method is so obviously wrong in principle it is remarkable that it has not been changed before.

In regard to the elimination of this "dust cushion" the author sees no better way than to simply mill a series of longitudinal slots in the standard abrasion cylinder through which the dust may escape as fast as it is formed. The slots adopted by the Bureau of Public Roads laboratory are 1½ inches apart, center to center, and one-sixteenth inch wide. A cylinder slotted in this manner has been in use in the laboratory for a number of years. The exact spacing or length of the slots, however, apparently makes very little difference in the actual results obtained, provided there are a sufficient number of openings to permit all of the dust to escape.

Several other suggestions in the way of improving this test, such as the use of small shot as an abrasive agent, a graded instead of a one-size sample, etc., have been offered from time to time. Some of these will be briefly discussed in the conclusions to this paper.

[4] Proceedings, Am. Soc. Test. Mats., Vol. XVIII, Part II, p. 417 (1918).

TABLE II.—*Results of comparative abrasion test for rock.*

No.	Type of rock.	Hardness.	Toughness.	Percentage of wear, standard test.	Percentage of wear, slotted test.	Difference.
1	Trap	18.7	35	1.6	2.4	0.8
2	.....do	18.7	.....	2.0	2.4	0.4
3	.....do	18.0	32	2.0	3.0	1.0
4	Granite	19.0	10	3.2	3.5	0.3
5	Trap	18.5	43	3.0	3.8	0.8
6	.....do	17.3	21	2.7	3.9	1.2
7	.....do	.....	.....	2.7	4.0	1.3
8	Granite	18.0	14	3.4	4.0	0.6
9	.....do	18.7	10	3.7	4.2	0.5
10	.....do	18.0	14	3.2	4.2	1.0
11	Trap	18.0	26	2.3	4.2	1.9
12	Granite	18.0	9	3.6	4.2	0.6
13	.....do	18.7	13	3.3	4.3	1.0
14	.....do	18.7	10	3.5	4.4	0.9
15	Quartzite	18.7	16	3.4	4.5	1.1
16	Granite	18.7	9	3.4	4.5	1.1
17	.....do	18.7	10	3.5	4.5	1.0
18	Trap	18.0	20	2.8	4.6	1.8
19	Granite	19.3	11	3.6	4.7	1.1
20	.....do	18.7	10	3.4	4.7	1.3
21	.....do	18.0	10	3.8	5.0	1.2
22	Quartzite	18.7	17	3.3	5.1	1.8
23	Limestone	17.2	15	3.5	5.1	1.6
24	.....do	17.3	.....	3.3	5.6	2.3
25	Granite	16.7	8	3.2	5.6	2.4
26	.....do	17.3	7	4.2	5.6	1.4
27	Trap	18.3	18	3.2	5.8	2.6
28	Granite	17.3	7	4.2	5.9	1.7
29	.....do	16.7	8	4.3	5.9	1.6
30	.....do	.....	7	4.4	5.9	1.5
31	.....do	18.0	9	4.3	6.0	1.7
32	.....do	16.7	8	4.5	6.1	1.6
33	.....do	18.0	8	5.2	7.2	2.0
34	Limestone	15.0	10	3.4	7.7	4.3
35	Sandstone	16.7	8	4.3	8.0	3.7
36	Trap	16.7	9	4.0	8.6	4.6
37	Limestone	17.3	15	4.8	8.8	4.0
38	.....do	12.3	6	3.3	9.3	6.0
39	.....do	16.0	8	6.0	10.2	4.2
40	.....do	12.3	6	4.7	10.4	5.7
41	.....do	13.9	8	5.3	10.6	5.3
42	Granite	18.5	6	6.8	10.6	3.8
43	Limestone	15.7	5	5.4	10.7	5.3
44	.....do	15.0	7	5.9	11.1	5.2
45	.....do	16.0	6	6.8	11.4	4.6
46	.....do	16.5	6	7.0	11.7	4.7
47	.....do	12.1	9	6.2	12.2	6.0
48	.....do	13.3	3	7.0	12.2	5.2
49	.....do	12.7	4	5.9	12.9	7.0
50	.....do	13.5	6	5.6	13.0	7.4
51	.....do	15.9	6	8.3	13.4	5.1
52	.....do	14.3	7	7.0	13.8	6.8
53	.....do	12.0	7	7.4	16.8	9.4
54	.....do	10.2	7	6.9	19.1	12.2
55	.....do	11.0	5	8.5	22.9	14.4
56	.....do	8.0	5	10.8	27.6	16.8
57	.....do	4.0	4	10.8	31.4	20.6

DISCUSSION OF RESULTS OBTAINED.

The work covered in the following discussion was carried out, therefore, with two primary objects in view:

1. To determine how variations in the results of tests due to laboratory manipulation may be reduced;
2. To determine the comparative range in values obtained with and without the "dust cushion."

The results of a number of tests made on samples prepared by machine and tested in the slotted abrasion cylinder are given in Table I, and may be compared to the values obtained in the ordinary manner and to which reference has already been made. It will be noted that the average maximum deviation of 0.8 per cent observed with the standard method has been reduced to 0.3 per cent by the use of machine-broken fragments. The individual losses, on the other hand, have been increased in varying amounts due to the elimination of the dust cushion. Tests in the closed cylinder using machine-broken fragments showed slightly lower average results than with the standard method, no doubt due to the absence of wedge-shaped or flat pieces which frequently find their way into a sample prepared in the usual way. The results of a number of tests on a large variety of rock types are given in Table II. These results are plotted in figure 2 in the order of their loss by abrasion in the slotted cylinder. They are of interest in showing the relative effect of the dust cushion as measured by the hardness of the rock. This relationship is plotted in figure 3 in which the hardness of the stone determined by the Dorry hardness test [5] is plotted against the difference, P-P', between the abrasion loss in the slotted and in the standard cylinder. Taking into account the fact that all of the test results given in Table II were obtained on samples hand-broken in the usual way and are liable therefore to a possible error of nearly one per cent, the relationship is fairly well defined, and shows clearly the value of using the slotted cylinder in differentiating between the wearing qualities of the softer types of rock.

In figure 4 are plotted the results of a number of tests made in both the standard and slotted abrasion cylinders in which the loss by abrasion was determined at the end of each 1,000 revolutions. A comparative run was made also in each case using six $1\frac{3}{8}$-inch cast-iron shot as an abrasive agent. These tests were made in order to determine the practicability of accelerating the wear by means of an abrasive and at the same time speeding up the test by cutting down the total number of revolutions. According to the results shown in the figure it would appear theoretically possible to obtain about the same loss at the end of 2,000 revolutions when shot are used as would be obtained at the end of 10,000 revolutions without the abrasive. As a matter of fact, however, experiments have shown that the gain in time thus effected would be more than counterbalanced by the resulting loss in accuracy. It has been found impossible to obtain check tests closer than 1 per cent when an abrasive is used, due probably to the breaking up of the fragments composing the sample under the action of the shot. This action makes the test a measure of toughness rather than of resistance to wear. Inasmuch as the amount of this action would depend to a large degree on the prevalence of insipient fractures or minute seams in the rock which would not affect the value of the material in road construction, the use of an abrasive is not recommended. The effect of these minute fractures which frequently can not be detected by the eye has been noted in connection with the standard test for toughness of rock.[6]

The following conclusions may be drawn:

1. Results of the standard Deval abrasion test as conducted in the usual way are accurate to within 1 per cent.

2. The difficulty of properly preparing samples by hand in a reasonable length of time is the principal reason for the discrepancies in results observed.

3. Samples may be prepared conveniently and accurately by means of the machine described in this paper.

4. The range in values of percentage of wear is greatly increased by the use of a slotted cylinder which permits the dust of abrasion to escape as fast as it is formed.

5. In general, the difference between percentage of wear as determined in the standard and in the slotted cylinder increases as the coefficient of hardness of the rock decreases.

[5] Bulletin No. 347, U. S. Department of Agriculture, p. 6.

[6] Proceedings, Am. Soc. Test. Mats., Vol. XVIII, Part I, p. 414 (1918).

THE CHARACTERISTICS OF STEAM DISTILLED PETROLEUM RESIDUALS[1]

By B. A. ANDERTON, Chemist, Bureau of Public Roads.

IN THE interpretation of the results of tests on bituminous road materials, it is well understood that a given set of values must be considered as a whole; in other words, the significance of almost any result is dependent upon other results or combinations of them. So in the preparation of specifications, the selection of suitable requirements to secure the desired materials must therefore be done with the influence of other requirements always in mind. We have all seen specifications for asphalts and road oils with which no commercial product could possibly comply on account of some unattainable requirement.

The writer is not aware that there is in the literature on bituminous materials any great amount of data on the relationships between the various tests with regard to the types of crude petroleum involved, and particularly as affected by the variations in process of manufacture. With the experience of many years' testing of bituminous materials, some general conclusions have been well brought out; as, for example, the relatively high specific gravity, insolubility in petroleum naphtha, and percentage of fixed carbon of products from Mexican petroleum; also, the relatively low ductility, high melting point, and high insolubility in naphtha of blown oils. But, in general, it is quite difficult to correlate available data in order to demonstrate specific relations along these lines, and in this paper the writer will endeavor to make some contribution to the subject which, while not entirely new material, may be of interest as setting forth in a definite manner the significance of some of our present tests.

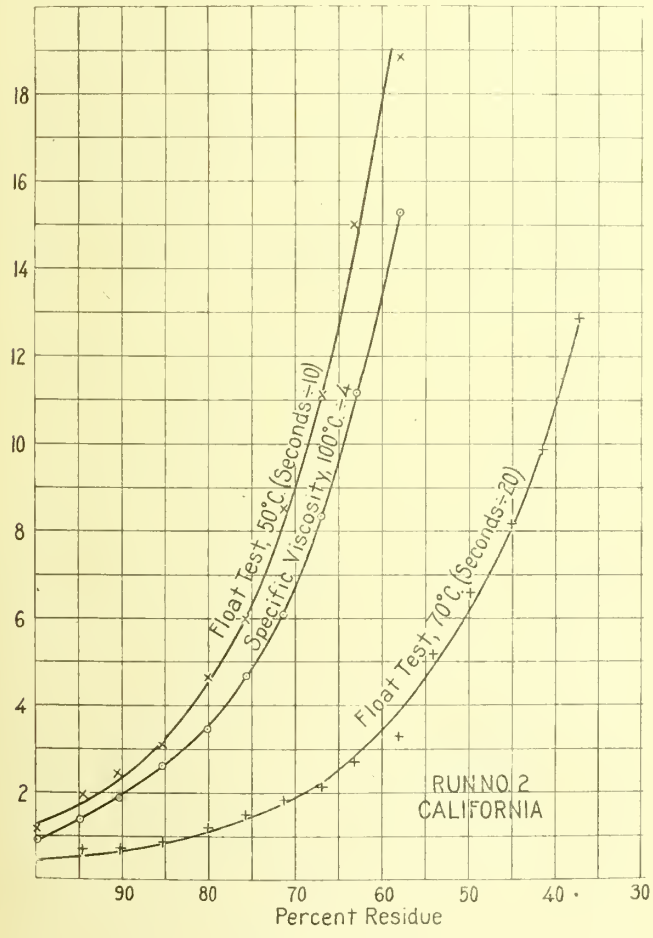


FIG. 1.—TYPICAL TESTS OF CONSISTENCY WITH PROGRESS OF DISTILLATION.

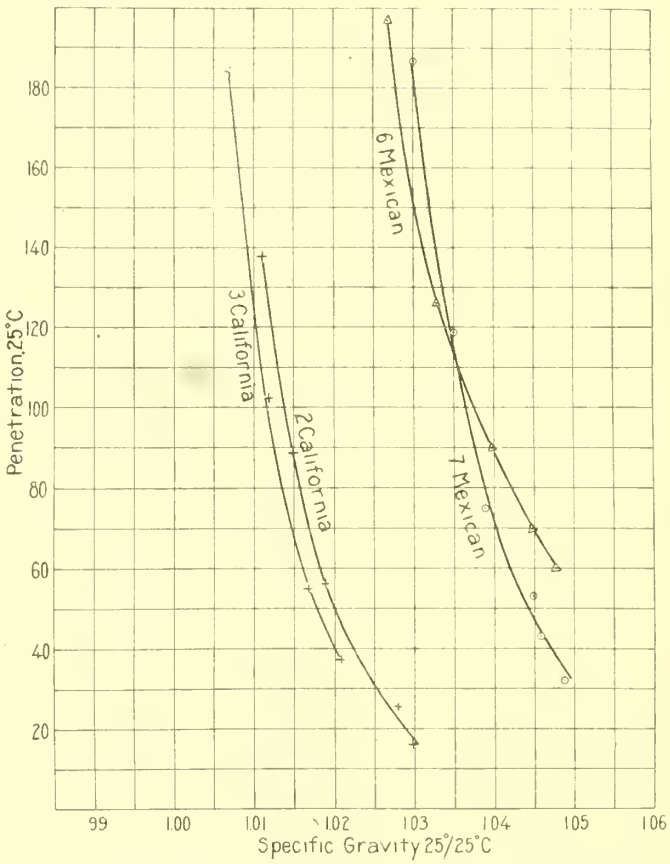


FIG. 2.—PENETRATION OF CALIFORNIA AND MEXICAN ASPHALTS SHOWING GREATER SPECIFIC GRAVITY OF MEXICAN PRODUCTS.

The opportunity to study the characteristics of petroleum residuals in this manner comes as a result of the operation of a small experimental refinery by the United States Bureau of Public Roads. A number of runs have been made, all of which up to the present time have involved steam distillation. Three typical crude petroleums have been used from California, southern Texas, and Mexican fields, respec-

[1] Paper presented at the annual meeting of the American Society for Testing Materials, Asbury Park, N. J., June 22–25, 1920.

tively, whose important characteristics are shown in Table I. During each distillation steam was passed through the still at such a rate as to maintain a fairly constant ratio of water to oil distillate in the flow from the condenser. These ratios were as follows:

Petroleum.	California.			Texas.		Mexican.	
Run No.	1	2	3	4	5	6	7
Average steam ratio	0.69	1.21	0.92	0.75	0.55	0.65	0.83

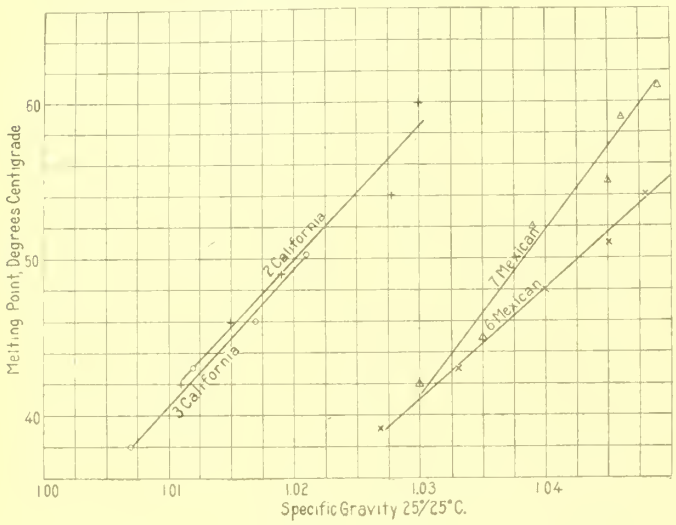


FIG. 3.—MELTING POINTS OF CALIFORNIA AND MEXICAN ASPHALTS SHOWING GREATER SPECIFIC GRAVITY OF MEXICAN PRODUCTS.

TABLE I.—*Characteristics of crude petroleum as shown by tests on three typical petroleums.*

Property.	Petroleum, source. California, Kern River.	Texas, Sour Lake	Mexico, Panuco.
Water, per cent by volume	6.0	0.0	2.9
Specific gravity 25°/25° C.	0.965	0.935	0.985
Flash point, degrees centigrade	115	54	52
Burning point, degrees centigrade	.....	122	110
Specific viscosity, Engler, 25° C.	.....	22.8	.....
Specific viscosity, Engler, 50° C.	.....	5.25	.....
Specific viscosity, Engler, 100° C.	2.82	1.60	.....
Float test, 32° C., seconds	.....	.....	40.6
Float test, 50° C., seconds	8.6	.....	26.5
Float test, 70° C., seconds	6.6	.....	16.5
Loss at 163° C., 5 hours, 50 g., per cent	8.76	15.70	11.73
Float test residue, 50° C., seconds	20.8	4.9	78.7
Float test residue, 70° C., seconds	.....	.....	38.3
Bitumen insoluble in 86° B. naphtha, per cent	3.4	0.31	20.09
Fixed carbon, per cent	3.58	1.38	10.77
Organic matter insoluble, per cent	0.01	0.07	0.09
Inorganic matter insoluble, per cent	0.0	0.06	0.09
Total bitumen (soluble in CS_2), per cent	99.99	99.87	99.91

As distillation proceeded, samples were taken systematically from the experimental still and tested, following the standard methods of the American Society for Testing Materials whenever they were applicable. Otherwise tests were carried out according to the methods in use by the Bureau of Public Roads.[1] It can readily be seen that these series of samples, all produced from the same still-charge of petroleum, and representing the changes in characteristics of the residuals taking place as the distillation continued, permit a study of interrelations between tests which could not ordinarily be accomplished with a collection of miscellaneous samples, affected possibly in different degree by variations in the original crude and in method of treatment. As an example of the development in consistency as the distillation progressed, figure 1, representing the specific viscosity and float tests of residues secured in one distillation of California petroleum, may be shown. Abscissae indicate the percentage of the crude removed as distillate or, on the scale given, the percentage of residue in the still. These curves are typical, not only of the graphical representation of other test results, but of other crudes. With very few exceptions, a smooth curve can be drawn with such plotted points, representing the actual relation of the two variables fairly well.

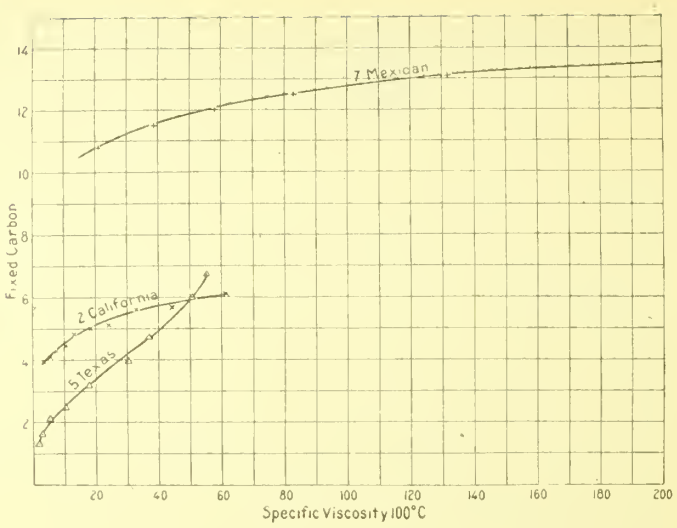


FIG. 4.—THE FIXED CARBON OF TYPICAL FLUID RESIDUALS.

Within the space of the present paper it will be possible to discuss only the most prominent relations

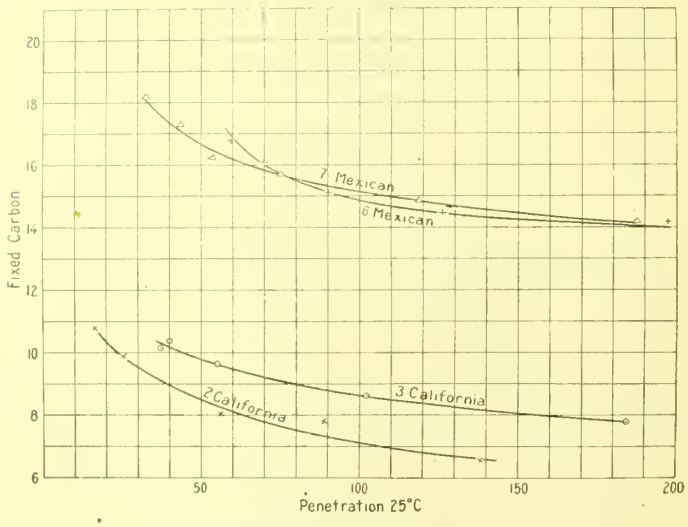


FIG. 5.—THE FIXED CARBON OF TYPICAL CALIFORNIA AND MEXICAN ASPHALTS.

[1] Methods for the Examination of Bituminous Road Materials, Bul. No. 314, U. S. Department of Agriculture.

which have presented themselves as a result of the work so far, which, as may be mentioned again, has dealt entirely with steam distillation. The samples examined should be considered as typical of their type; and little attempt will be made to discuss the test results theoretically, or to derive mathematical relationships, as it is felt that the scope of the available data is at present too limited for discussion of that nature. The data are presented graphically, requiring in most cases little explanation or comment.

Tests have shown clearly the greater density of Mexican asphalts. In figure 2, asphalts up to 200 penetration produced from the Mexican petroleum have a specific gravity of about 0.02 to 0.03 higher than for corresponding California products. It will be noted that there is a distinct difference in the two curves 6 and 7, although in both runs the crude was the same Mexican petroleum. This may be explained by the use of a greater volume of steam during distillation 7.

In figure 3 the greater specific gravity of Mexican asphalts than of California asphalts for a given melting point is shown. The difference is more significant when it is borne in mind that a California asphalt of the same melting point is considerably harder at normal temperature, as will be shown later. In figure 3 it has seemed best to represent the relations as straight lines, owing to the small number of points and having in mind the accuracy of the tests. The divergence between the two Mexican series is again noted.

Considering the percentage of fixed carbon in Mexican, California, and Texas residuals, figure 4 will show the high percentage for Mexican products, increasing slowly with specific viscosity at 100° C.

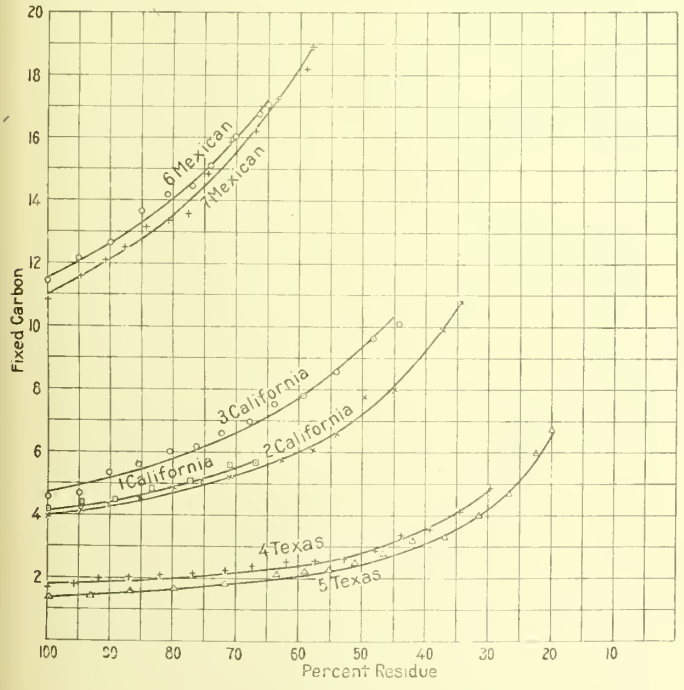


FIG. 6.—THE DEVELOPMENT OF FIXED CARBON IN STEAM DISTILLATION.

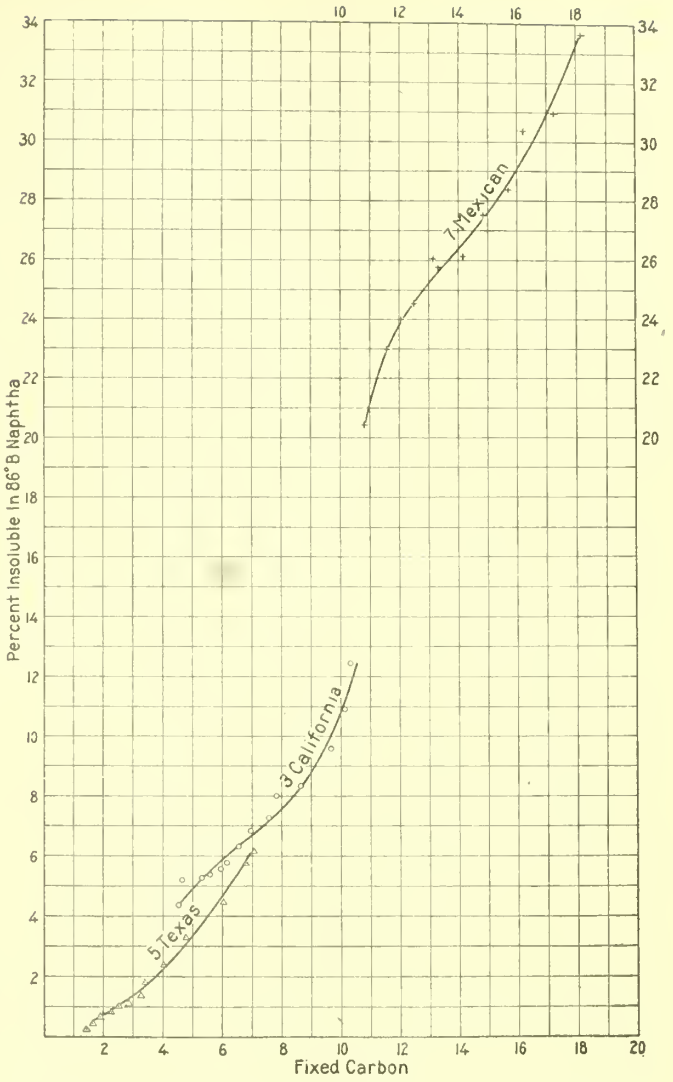


FIG. 7.—GENERAL RELATION BETWEEN FIXED CARBON AND PERCENTAGE OF BITUMEN INSOLUBLE IN 86° B NAPHTHA.

The Texas residuals increase rapidly in fixed carbon, but it is of interest to note that the final point on this curve represents a residue of only 20 per cent of the crude oil, attained at a high still temperature. The Texas petroleum would produce by steam distillation alone only a small quantity of residuals suitable for road work, and most likely of an inferior quality.

The higher fixed carbon for Mexican asphalts of less than 200 penetration is demonstrated in figure 5. Comparison with figure 2 will show that the form and relation of the two Mexican curves is similar, indicating a closer relation between specific gravity and fixed carbon.

An interesting relation which apparently is independent of the type of oil used, and which may point out the specific value of the fixed carbon test, should be discussed at this point. If the percentage of fixed carbon for successive residues is plotted against the percentage of residue, as in figure 6, it is noticed that in general the plotted points show a tendency

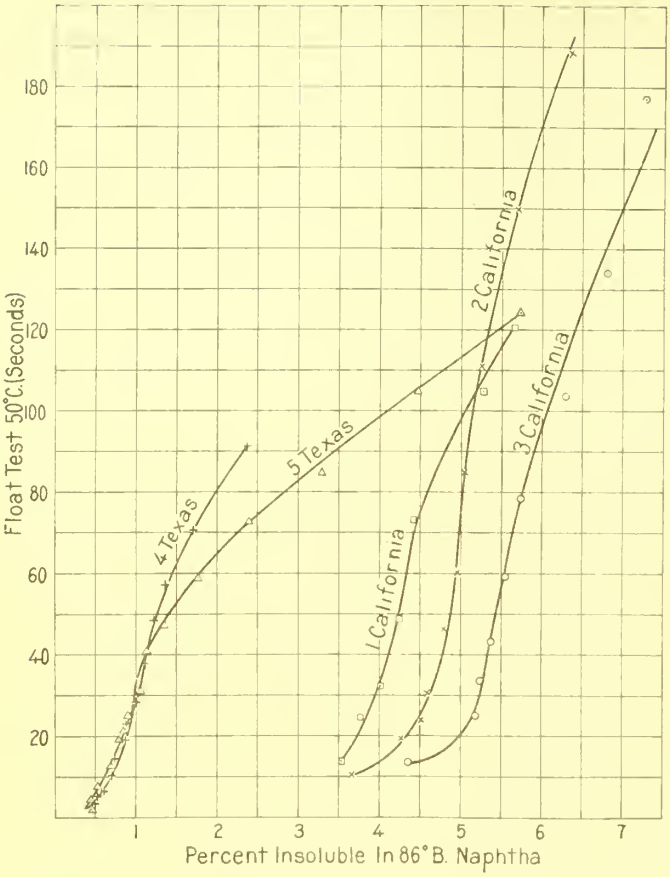


FIG. 8.—THE NAPHTHA INSOLUBLE OF FLUID TEXAS AND CALIFORNIA RESIDUALS.

to lie along the curve of a hyperbola. Also, by multiplying the percentage of fixed carbon by the percentage of the still charge represented by the corresponding residue, the series of values shown in Table II is obtained.

TABLE II.—*Product of fixed carbon by percentage residue of still charge.*

Designation of residue.	California.			Texas.		Mexican.	
	1	2	3	4	5	6	7
R0	4.15	3.95	4.52	1.68	1.38	11.48	10.80
R2	4.17	3.87	4.40	1.72	1.34	11.58	10.75
R2	3.99	3.87	4.81	1.74	1.39	11.42	10.95
R3	3.99	3.83	4.79	1.71	1.32	11.66	10.93
R4	3.89	3.88	4.48	1.64	1.32	11.46	11.08
R5	3.75	3.80	4.70	1.54	1.36	11.17	10.79
R6	3.79	3.64	4.75	1.56	1.31	11.18	10.55
R7	.....	3.76	4.74	1.57	1.25	11.27	11.06
R8	.....	3.59	4.82	1.52	1.28	11.11	11.26
R9	.....	3.52	4.64	1.45	1.31	11.08	10.86
R10	.....	3.58	4.67	1.38	1.35	.....	10.91
R11	.....	3.89	4.68	1.39	1.24	.....	10.71
R12	.....	3.60	4.49	1.45	1.26	.....	10.92
R13	.....	3.70	.....	1.41	1.27	.....	.....
R14	.....	3.71	.....	1.41	1.35	.....	.....
R15	.....	3.44	.....	1.46	1.35	.....	.....
R15.A	.....	.....	.....	1.32	1.29	.....	.....
Average	3.96	3.66	4.65	1.53	1.32	11.34	10.91
Mean deviation	.13	.14	.12	.11	.04	.18	.12
Maximum deviation	.21	.29	.25	.21	.08	.32	.36

It will be seen that for all distillations the values for a given run are practically constant. Judging from the deviations from an average value, they are as constant as should be expected with the fixed carbon test. Accepting the constancy of the product, the relation may then be expressed by the equation

$$RC_R = 100\,C_{100}$$

where C_R is the percentage of fixed carbon of a steam distilled petroleum resudual, which is R per cent of the original having a fixed carbon of C_{100} per cent. In this connection it may be noted that subsequent work in which residuals have been air-blown has shown that blowing materially increases the percentage of fixed carbon.

In figure 7 the general tendency of the fixed carbon and percentage of bitumen insoluble in 86° Baumé naptha to increase together is shown.

The proportional rate of increase for a given material, however, evidently varies quite widely, and in this curve, as in some others involving naphtha insoluble it is indicated that at some point in the distillation, reactions begin within the petroleum, gradually increasing in importance as the temperature rises, which result in the actual formation of bodies of an asphaltic character. Particularly is this evidenced in figure 8, when the naphtha insoluble is plotted against consistency by the float test at 50° C.

The reversal of curvature is quite striking in this diagram. If the point at which the curvature reverses is estimated from the graphs, and taken at a float test of 30 seconds for the Texas, and 60 seconds in the case of the California, it may be of interest to add that the temperature of the Texas oil at this point in the distillation was 295 to 300° C., while the California oil had a temperature of 250 to 260° C.

That some asphaltic products soften more readily upon heating than others and that this susceptibility to heat may be greatly modified by variation in the process of manufacture, are well understood facts. In specifications for paving asphalts, therefore, various combinations of requirements for melting point, ductility, penetration at 0° or 46° C., etc., together with the consistency at normal temperature, are

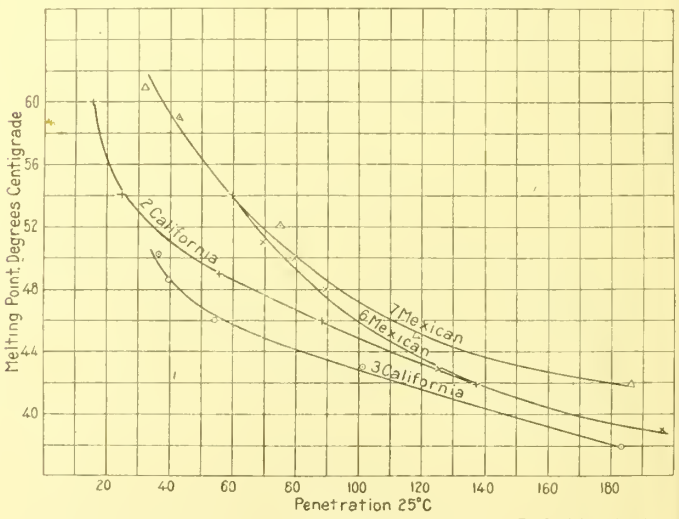


FIG. 9.—THE MELTING POINT OF MEXICAN AND CALIFORNIA ASPHALTS.

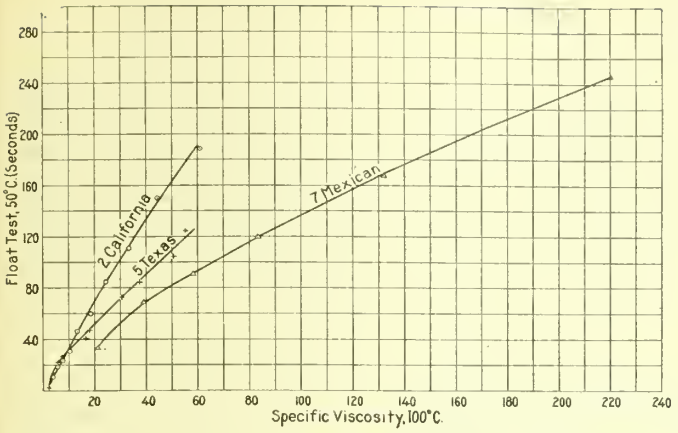


FIG. 10.—THE FLOAT TEST OF TYPICAL FLUID RESIDUALS.

utilized to secure a material having suitable qualities for the particular work in hand. The variation in ball and ring softening point for typical Mexican and California asphalts is shown in figure 9.

Another test which, though looked upon usually as a consistency test, is not often utilized to investigate susceptibility to temperature, may be used to advantage on a wide range of products. This is the float test. That this test is essentially a test of viscosity is made apparent by the great similarity of the curves shown in figure 1. The results of the float test are, however, greatly influenced by the way in which the material tested softens on heating, and consequently, as the bath temperature is set at a higher point, the test becomes more and more a measure of the susceptibility of the material. It may be considered as giving a measure of viscosity combined with susceptibility. Figures 10 and 11 will illustrate this. In figure 10, the California, Texas, and Mexican products show a decreasing susceptibility, in this order, by having a lower float test at a lower temperature for the same specific viscosity at 100° C.

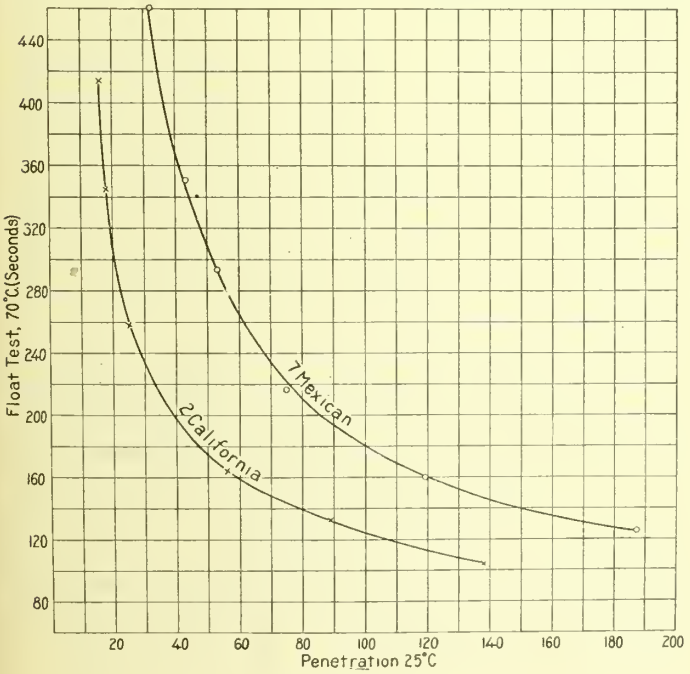


FIG. 11.—THE FLOAT TEST OF MEXICAN AND CALIFORNIA ASPHALTS.

A large number of float tests have been made at 70° C., in order to secure data on the change in consistency over a wide range of products, especially to cover the range of consistency where the viscosity test at 100° C. or the penetration at 25° C. is not readily applicable. The results of these tests on the harder asphalts also indicate the greater susceptibility of the California products, as may be seen in figure 11.

As the penetration increases, the difference in float test becomes more marked; at 35 penetration the Mexican asphalt gives a float test twice that of the California asphalt.

It will be realized that the relations which the writer has tried to bring out graphically represent data compiled from typical petroleums only, and that the characteristics of residual oils and asphalts may be greatly modified by changes in method of refining. In the writer's judgment, two features—the significance of the fixed carbon test in relation to the progress of steam distillation and the development of the float test as a measure of viscosity and susceptibility to temperature changes—should prove the two points of greatest interest and value resulting from these tests.

INDIANA ROAD CONSTRUCTION IS STANDARDIZED.

Uniform road construction is expected throughout Indiana as a result of an order issued by the State highway commission requiring the standardization of road plans and specifications for county highways which are subject to the approval of the commission. The regulation became effective July 1 and covers all county road projects submitted to the commission for approval.

The regulation is similar to the Federal order requiring the use of standardized plans and specifications by the State for all roads for which Government aid is expected. The action of the commission extends the use of the approved standards to the roads which will be built in Indiana under the provisions of the county unit road law, by which the State shares the cost.

Officials of the commission have compiled the standards for the Indiana roads, which are identical with the requirements made of the State by the Federal Government. The standards will apply to all county-aid projects proposed under the State highway law, the county unit road law, and the free gravel road law.

Many counties of the State already have adopted the commission standards voluntarily to keep their road construction up to the specifications prescribed by the Federal and State engineers.

Members of the commission, in discussing the regulation, declared that it will have the effect of standardizing road construction throughout Indiana.

GOOD PROGRESS IN IMPACT TESTS.

THE investigations now being made by the Bureau of Public Roads to determine the forces exerted by motor trucks on roads are showing some very instructive results. Various sizes of trucks have been used in these tests varying from a 1-ton truck up to a 7½-ton truck carrying an excess load. The truck is run over a special device for producing artificial impact conditions and the impact pressure is measured through the deformation of specially prepared copper cylinders. The blow of the truck deforms the copper cylinder and the magnitude of the blow is expressed in pounds required to deform the cylinder, the latter being determined in a testing machine.

Recent tests were made with a 3-ton Packard truck loaded with a 4½-ton load so that the total weight on each rear wheel was 7,000 pounds, the unsprung portion being 1,700 pounds and the sprung portion 5,300 pounds. The truck was equipped first with an old solid tire that had been worn down to a thickness of 1 inch. Then, with exactly the same load on the truck, a wheel was used fitted with a new solid tire 2½ inches in thickness. And finally, the truck was equipped with pneumatic tires 42 by 9 inches inflated to a pressure of 142 pounds per square inch. The following table shows very clearly the bad effect an old tire is likely to have on a road surface and the comparative lack of impact when trucks are equipped with pneumatic tires:

Approximate speed.	Height.	Old tire.	New tire.	Pneumatic tire.
	Inches.			
5.7	2	11,600	9,400	7,100
10.2	2	18,500	14,100	7,800
14.6	2	26,500	18,700	8,300

The question of impact is one of very great interest to those who are called upon to decide upon road design, and it is probable that the results of these tests may lead to a rational basis for determining license fees.

IMPACT ON SURFACES OF DIFFERENT TYPES.

A number of slabs have been tested by means of a machine designed to give impact conditions resembling those on the rear wheel of a heavy truck. The unsprung portion of the weight of this machine is 1,500 pounds and the sprung portion weighs 6,000 pounds. The test is made by raising the unsprung weight through a height of one-eighth of an inch, allowing it to fall 500 times, then to a height of one-half inch with 500 repetitions, then three-eighths inch more in height, and so on until the slab fails. Up to date about 12 slabs have been tested when laid on a rather wet subgrade and there is a surprising difference in the strength of the different types of pavements tested. Thus, the total number of blows required to cause failure have varied with the different slabs from 67 up to almost 2,000. It is expected that a detailed account of the results of these tests will be published toward the end of the summer.

RELATIVE WEAR OF DIFFERENT PAVEMENTS.

The bureau is making a study of the relative wearing qualities of different types of pavements and tests have about been completed on a short section of pavement containing 49 different types subjected to the wear of a special truck equipped with five large cast-iron wheels. The results of this investigation are very instructive and bring out very many interesting points in connection with pavement design. The relative wearing qualities of hard as compared with soft brick are brought out very distinctly in this test. The relative resistance to wear of various kinds of stone block sections is also shown up to good advantage. A chance to compare grout and asphalt fillers for both brick and stone block is furnished by this investigation. Likewise, the relative wearing qualities of concrete when mixed with various kinds of coarse aggregates is indicated. Results of this test are also being worked up in a paper to be published within a very short time.

INVESTIGATION OF SUBGRADE MATERIALS.

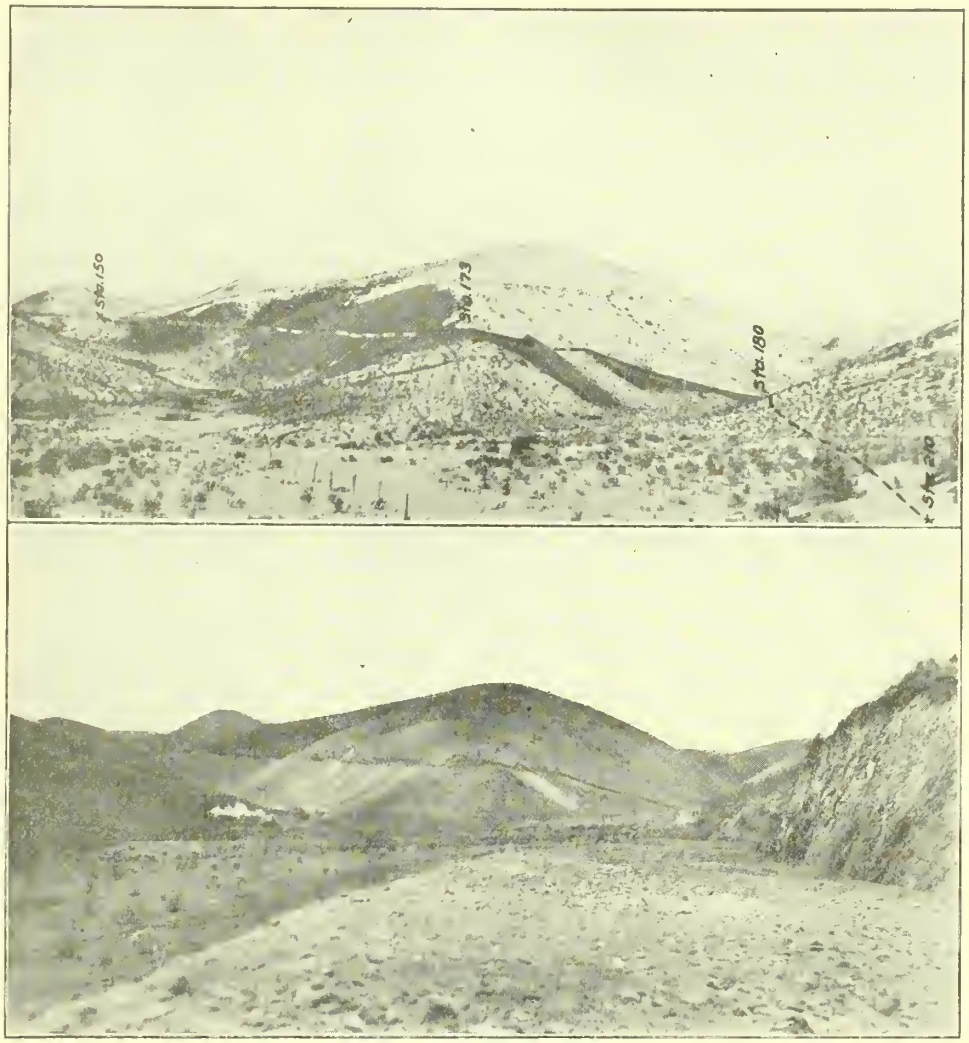
The investigation of subgrade materials started a few months ago with the cooperation of the district engineers and State engineers is proceeding at a very satisfactory rate. A number of samples have been received from various parts of the country and laboratory analyses of many of these samples are partially completed. The methods being used by the Division of Tests have been described and will shortly appear as a paper so that any other laboratories wishing to conduct similar investigations may have some guide as to the method of procedure being followed by the Bureau of Public Roads.

The samples analyzed have been taken from parts of the roads that have failed very badly as well as from adjacent parts of the same roads that have withstood heavy traffic successfully. It is hoped that by a comparison of the laboratory results on these samples with the reported behavior of the road in service differences in the subgrade materials will become apparent so that we will be able to say what physical characteristics soils must possess to give them high bearing value.

PHOTOGRAPHIC HINTS FOR ENGINEERS.

By JOHN K. HILLERS, Jr., Photographer, Bureau of Public Roads.

SO MANY and important are the uses of photography in connection with engineering works that the camera has become almost as essential as the transit as an engineering instrument. Indeed, it can often be made to do much of the work of the latter instrument, as witness the part it played in France in the mapping of the battle-front areas. No great use has been made of it in this way in connection with highway work, but the writer is not at all convinced that it has not valuable possibilities which have so far been overlooked. Just a suggestion of its usefulness in making reconnaissance surveys is contained in the pictures reproduced on this page. As for its value in recording details of construction for the illustration of engineering reports, as a means of studying the causes of deterioration of engineering structures by preserving a record of the appearance of the structure at various stages of failure, and as a means of picturing the tangible results of engineering vision—these uses are too well understood by the engineering profession to require any dwelling upon.



TOP, A GENERAL VIEW OF OREGON FEDERAL-AID PROJECT NO. 17, FROM STATIONS 150 TO 210, PHOTOGRAPHED ON JANUARY 10, 1920, BEFORE WORK WAS STARTED, LOCATION SHOWN BY DOTTED LINE. BOTTOM, VIEW OF THE SAME LOCATION SHOWING THE COMPLETED GRADE.

But though practically all engineers appreciate the value of the camera as an aid to them in their daily work, there are many, unfortunately, who fail to make the most of it, largely for the lack of a working understanding of a few simple principles. In this article the writer will not attempt to do more than call attention to these principles, the application of which by engineers generally will go far to improve the character of engineering photography.

STUDY THE LENS.

The most important part of any camera, of course, is the lens. It is the eye of the camera, and, like its human counterpart, it has its limitations. Not only are differences in performance to be expected of lenses of different kinds and by different makers, but even among stock lenses of the same kind and by the same maker there are differences of sufficient importance to make it decidedly worth while for engineers to follow this first bit of advice—"get acquainted with your lens." Test it—"calibrate" is the engineering term, I believe—calibrate it, then, by trying it with various exposures and different openings in all sorts of light and upon all sorts of objects close at hand and far away. Preserve a record of the conditions and the manner of taking each picture and compare the results to determine the limitations and capabilities of your particular lens.

The lenses used by engineers generally are of two classes, known respectively as the rapid rectilinear lens and the more modern anastigmatic lens. The latter was developed to correct the defects of the

rapid rectilinear lens which are manifested by a certain cloudiness around the edges of photographs taken with a large opening and short time. The anastigmats will give good definition under these conditions, and in this feature alone lies their superiority to the ordinary rapid rectilinear lens. Many engineers seem to think they must have an anastigmatic lens to enable them to take good photographs. It is not at all necessary, and really, is altogether unnecessary, if exposures be made, as they should be in nearly all engineering work, with a small opening and relatively long time. Under these conditions the ordinary rapid rectilinear lens will give entirely satisfactory results.

THE STOP AND LIGHT.

Next to the lens in importance are the shutter and diaphragm, which together constitute the lids which open and close over the eye and regulate the amount of light admitted to the sensitive film at the back of the camera. The shutter, a set of flanges, which when properly operated, open and close across the lens, regulates the duration of exposure. The operation is controlled either by a cable release, a bulb, or by a small lever at the side of the shutter. By the adjustment of the small pointer at the top of the lens the shutter can be set to open when pressure is applied to the control and remain open until a second pressure is applied, or to remain open only as long as the pressure is maintained. These two positions, known as "time" and "bulb," and designated on the scale as T. and B., are used for long-time exposures. In addition to them there are other positions for the pointer, at which the shutter will open and automatically close after one-hundredth, one-fiftieth, one-twenty-fifth, and one-fifth of a second, respectively.

The iris diaphragm or aperture consists of a series of flanges which can be regulated to alter the size of the opening through which light is admitted to the lens. The settings or stops of these flanges, which form the openings which have become standard and which are now afforded by all cameras, are designated in accordance with two systems of numerals. The systems of designation are the U. S., or uniform system, and the F. system of the Royal Photographic Society, wherein the opening is expressed by fractions of the focal length. The openings designated by these two systems, however, are identical in size, the identity being as indicated in the following table:

Comparison between the F. and U. S. systems.

F. system....	F. 4.5	F. 8	F. 11.3	F. 16	F. 22	F. 32	F. 45
U. S. system...	1.2	4	8	16	32	64	128

By the proper combination of time of exposure and size of opening the light is admitted to the sensitized film through the lens in just the amount which is necessary to imprint the desired image upon the film surface. The same amount of light may be admitted either by the combination of a large opening and a short exposure, or by long exposure with a small opening, but the results of the two combinations will differ. The picture taken with the large opening and short exposure will present a more or less flat aspect, lacking in depth or the quality of distance and in sharpness of definition or detail. The picture taken with the small opening will be sharp in definition; minute details, such as the leaves of trees, will stand out prominently, and the perspective will be well developed. It follows, therefore, that if one wishes to obtain a picture in which detail will be subordinated, as when it is desired to minimize the defects of a road surface, the large opening and short exposure make the proper combination. If, on the contrary, as should be the case in engineering pictures, the desired result involves the sharp definition of detail, the proper procedure is to use a small opening and a long exposure. It is for this reason that the rapid rectilinear lens should be as useful to the engineer as the anastigmatic lens.

In comparing the work of these two lenses, however, one must remember to compare pictures taken with a stop opening of the same relative size (F. value). Do not expect as great depth of focus with an anastigmat set at an opening of F. 6.3, as the rapid rectilinear lens gives at its largest opening, No. 4, corresponding to F. 8. The anastigmat at F. 8 will give as great depth of focus as will a rapid rectilinear lens of the same focal length, with the same opening while, on the other hand, the rapid rectilinear will not work at all at F. 6.3.

FOCUSING.

No matter what camera you are operating you must look to the focusing as well as to the stop and light. All engineers are familiar with the small focusing scale which is carried on practically all cameras. Set at any of the figures from 6 to 100 with which such scales are usually marked, the lens will be brought to the proper distance from the focal plane (*i. e.*, the surface of the film) to focus sharply upon an object at the distance indicated. If the camera be set in this manner for a focus of 100 feet, every object from a point at that distance on to the horizon will be in focus, regardless of the size of the opening. Objects closer than 100 feet to the camera, however, will not be sharply defined unless the diaphragm be stopped down to a small opening. If, instead of setting the focus at 100 feet, it be set at 25 feet, it will be found that the only objects which will be in sharp focus, if the aperture be large, will be those which lie in a plane at a distance of 25 feet from the camera. Objects nearer at hand and farther away will be out of focus unless the size of the aperture is reduced.

To obtain a first-hand knowledge of the effect of the size of the aperture upon the sharpness of the focus, it would be an excellent thing if every engineer

would try this simple experiment at the first opportunity: Place a camera on a tripod and point it at some object, a tree, for instance. Remove the back of the camera and place a piece of ground glass in its place. Set the diaphragm for the largest opening and open the shutter. With the head about 1 foot away, and the eyes on a level with the camera, throw a piece of black cloth over the head and the back of the camera to cut off the light except that entering through the lens. When the eyes become accustomed to the darkness, an inverted image will be seen upon the ground glass. Now move the lens back and forth until the tree is sharply defined on the ground glass. If the tree selected is about 25 feet away, the rest of the picture or the distance from the tree to the lens and from the tree to the horizon will be out of focus. Now stop down the diaphragm first to 16, then to 32, and finally to 64. At each stage it will be observed that the image becomes fainter and fainter and at stop 64 it will be difficult to see it. But coincidently the image becomes sharper and sharper and, by looking closely when the stop is at 64, it will be noticed that everything in the picture is sharply defined. This simple experiment will impress upon anyone, better than anything the writer can think of, the fact that the size of the aperture or the stop that is used has its effect upon the focus of the picture as well as upon the amount of light admitted.

For the ordinary purposes of the highway engineer a much better picture will be obtained by focusing on a point 25 feet distant from the camera and stopping down for definition than by focusing at 100 feet and using a large opening. The former practice will reproduce in clean-cut definition all the immediate foreground where the objects will be large enough to show small detail and will picture with at least as great a degree of sharpness as can be obtained by the second method all objects at whatever distance from the camera.

In using the first method, however, it is of course necessary to increase the time of exposure as the size of the aperture is reduced; and right here is where the tripod comes into its own.

The average field engineer, to whom it becomes second nature "to consider the size of his pack to save his back" objects to the tripod as so much useless weight to be dragged around. For the same reason he selects a 3A rather than a 4A Kodak. But while it is not particularly important which size of camera he uses, since photographs can be enlarged or reduced to any size at pleasure, when it comes to the tripod "there's a reason." And in the opinion of the writer the reason is so pertinent that he is convinced that the failure to give heed to it is responsible for much that is mediocre and more that is positively poor in engineering photographs.

BE SURE OF THESE THINGS.

In making engineering photographs it is best to use the tripod for both time and instantaneous exposures. Having set the instrument, be sure of four things:

First. That the shutter is set properly (for time or instantaneous exposures as desired).

Second. That the diaphragm stop is set at the proper opening.

Third. That an unexposed section of the film is turned into position.

Fourth. That the camera is focused on the principal object to be photographed.

After placing the camera on the tripod, select the view. Look over the subject carefully and estimate what stop and time of exposure will be suitable for the conditions as to light and color of object. For cloudy days the writer uses an exposure of $\frac{1}{2}$ second and the 32 stop; on bright days $\frac{1}{5}$ second and 32 stop; very bright days $\frac{1}{5}$ second and the 64 stop or $\frac{1}{2}$ second and the 128 stop. Remember that you must give the picture sufficient light to develop the darkest places. An old by-word among photographers is "photograph the shadows and let the high lights take care of themselves." And don't forget that the general color of the surroundings has a lot to do with the adjustment of the aperture. On roads or structures other than concrete, $\frac{1}{5}$ second and the 32 stop will give good results on a bright day. Concrete requires less opening than dirt, macadam, or bituminous macadam.

If the camera must be pointed into the sun, shield the lens from the direct rays with a hat or notebook.

If there is action in the picture use an exposure of $\frac{1}{25}$ or $\frac{1}{50}$ of a second and a stop of 8 or 16, according to the brightness of the day. If there is anything as fast as a moving automobile or railroad train, don't use any exposure longer than $\frac{1}{100}$ second.

Best of all, if there is doubt as to the working of the camera, follow the advice given early in this article. Take six exposures of the same picture, varying the opening, and be sure to record the exposure and opening, and then check the results against the record. If the films are developed in the field ask the photographer not to cut them apart.

AS TO THE SUBJECT.

The hints which have been given so far deal with the manipulation of the camera. Perhaps that is the only subject upon which the writer is competent to speak; but so many pictures have passed through his hands, in which there is evident a lack of regard for the preparation of the subject that a few words on that matter may not be amiss.

If the aim is to show the details of a structure or a road, or a road failure, or what not, mount the camera as close to the subject as possible in order to include in the picture all that is desired. Get the subject in the foreground where the details will be large, and then stop down for definition.

If dimension is of the essence of the subject, lay a white rule in the picture where the figures will show prominently, or get a man into the photograph with whom to compare sizes.

If the subject is a depression or an elevation below or above a general surface, take the photograph at a time of day when the length of the shadow will bring out the depth or height of the subject. Such a picture taken at midday will not be satisfactory. For this purpose it is best also to photograph into the sun.

If the picture is a construction picture, in which the workmen are supposed to be at work, try to catch them before they know they are being photographed; but if they must know it, ask them as one gentlemen

[Concluded bottom column 2, next page.]

LAST APPORTIONMENT OF FEDERAL AID.

THE last apportionment of Federal funds to aid the States in road construction under the existing Federal aid act became available July 1. This will be the largest apportionment yet certified under the Federal aid act, amounting to $100,000,000, three-quarters of which is derived from the appropriation of 1919 and $25,000,000 from the original appropriation of 1916. A deduction of $3,000,000, or 3 per cent of the funds, will be made to provide for the expense of administering the Federal aid act by the Department of Agriculture. The balance of $97,000,000 will be divided among the States in proportion to their population, area and mileage of post roads. The allotments to the several States from the two portions of the fund are given in the table of apportionment printed below.

Under the law the States are required to enter into formal agreements with the Secretary of Agriculture for the construction upon which this money is to be used before July 1, 1922. Any money which is not taken up before that time will be reapportioned among all the States in the same manner in which the original apportionments are made. All previous apportionments have been taken up in the time allotted, and it is not likely that the States will fail to absorb this last apportionment. To do so, however, will mean that the States must survey, plan, and let contracts for at least $200,000,000 worth of Federal aid road construction in the next two years.

If the States continue to pay more than 50 per cent of the cost, as they have in the past, the cost of the roads constructed with this last apportionment may reach $250,000,000. In other words, it will be necessary to plan for construction at the rate of at least $100,000,000 and probably more per year. Some appreciation of what that means may be gleaned from the fact that in 1915 the expenditure for all roads in the United States, constructed under State supervision, was only $80,000,000.

Since 1915, however, State highway departments have been greatly expanded, and efficient machinery has been developed which will undoubtedly be able to handle the greater volume of work.

Remainder of 1916 Federal aid appropriation.

	Sum apportioned.		Sum apportiond.
Alabama	$526,220.88	Minnesota	710,522.33
Arizona	313,411.04	Mississippi	451,889.29
Arkansas	421,294.52	Missouri	846,974.90
California	763,668.88	Montana	501,747.53
Colorado	438,939.79	Nebraska	533,435.50
Connecticut	153,337.36	Nevada	319,086.11
Delaware	40,668.70	New Hampshire	103,709.73
Florida	286,861.98	New Jersey	296,889.11
Georgia	674,287.74	New Mexico	399,616.96
Idaho	306,512.48	New York	1,242,973.28
Illinois	1,091,266.98	North Carolina	569,763.45
Indiana	671,763.32	North Dakota	384,056.95
Iowa	720,332.18	Ohio	926,561.70
Kansas	717,811.16	Oklahoma	575,619.53
Kentucky	487,938.86	Oregon	394,038.01
Louisiana	340,557.78	Pennsylvania	1,147,986.51
Maine	240,057.54	Rhode Island	58,314.22
Maryland	216,749.65	South Carolina	359,004.76
Massachusetts	368,197.21	South Dakota	403,944.86
Michigan	722,916.99	Tennessee	565,478.48

Remainder of 1916 Federal aid appropriation—Continued.

	Sum apportioned.		Sum apportioned.
Texas	1,465,399.62	West Virginia	265,038.19
Utah	282,393.91	Wisconsin	636,236.34
Vermont	112,519.27	Wyoming	308,428.96
Virginia	494,418.46		
Washington	361,156.95	Total	24,250,000.00

Apportionment of 1919 Federal aid appropriation.

	Sum apportioned.		Sum apportioned.
Alabama	$1,578,662.63	Nevada	$957,259.32
Arizona	1,030,233.12	New Hampshire	311,129.20
Arkansas	1,263,883.57	New Jersey	890,667.34
California	2,291,006.63	New Mexico	1,198,850.89
Colorado	1,316,819.38	New York	3,728,919.83
Connecticut	460,012.07	North Carolina	1,709,290.35
Delaware	122,006.11	North Dakota	1,152,170.85
Florida	860,585.94	Ohio	2,779,685.11
Georgia	2,022,863.22	Oklahoma	1,726,858.75
Idaho	919,537.45	Oregon	1,182,114.02
Illinois	3,273,800.93	Pennsylvania	3,443,959.54
Indiana	2,015,289.95	Rhode Island	174,942.65
Iowa	2,160,996.56	South Carolina	1,077,014.28
Kansas	2,153,433.46	South Dakota	1,211,834.58
Kentucky	1,465,816.57	Tennessee	1,696,435.42
Louisiana	1,021,673.35	Texas	4,396,198.84
Maine	720,172.62	Utah	847,181.75
Maryland	650,248.96	Vermont	337,557.82
Massachusetts	1,104,591.62	Virginia	1,483,255.37
Michigan	2,168,750.98	Washington	1,083,470.84
Minnesota	2,131,567.00	West Virginia	795,114.58
Mississippi	1,355,667.88	Wisconsin	1,908,709.01
Missouri	2,540,924.70	Wyoming	925,286.88
Montana	1,505,242.60		
Nebraska	1,600,306.43	Total	72,750,000.00

PHOTOGRAPHIC HINTS FOR ENGINEERS.

[Concluded from page 21.]

of another please to look busy. Our own files are full of pictures which, taken collectively, would prove beyond the peradventure of a doubt that workmen never work.

If the picture is to represent a finished road or structure, see that it is really finished before it is photographed. See that the ditches and shoulders are trimmed; that the road surface is clear of litter and free of defect, and, unless construction details limit, take the picture so as to include a beautiful tree or some bit of scenery that will add to the beauty of the picture.

At times, roads are constructed in which the alignment or the grades, the location in other words, is not all that it should be in places. Sometimes such faults are deliberately passed over in the plans for economic reasons, or for numerous other reasons; sometimes thay are the result of poor design or oversight. If the faults themselves are to be the subject of the pictures, emphasize them by a suitable set-up. An ugly break in the grade will show up best from a set-up at a distance and slightly to one side of the road, which will make it stand out much like an angle in alignment. Angles in alignment can be caught best by shooting along the edge of the road rather than along the center. The same is true of wavy edges of concrete roads.

But unless the defect is to be the subject, try to take the picture in such a way as to exclude it. There are few things more beautiful than a perfect road threading its way over hill and dale, and promising fresh delights at every turn to all who will follow it. Pictures of such roads speak more eloquently of the benefits of improved highways than the most carefully developed argument of engineer or economist. They are valuable, therefore, not only as a record of completed work, but as an inspiration to all who see them for more roads and better roads.

THE MANUFACTURE AND USE OF LABORATORY DIAMOND CORE DRILLS.

By F. H. SCHLOER, Instrument Maker, U. S. Bureau of Public Roads.

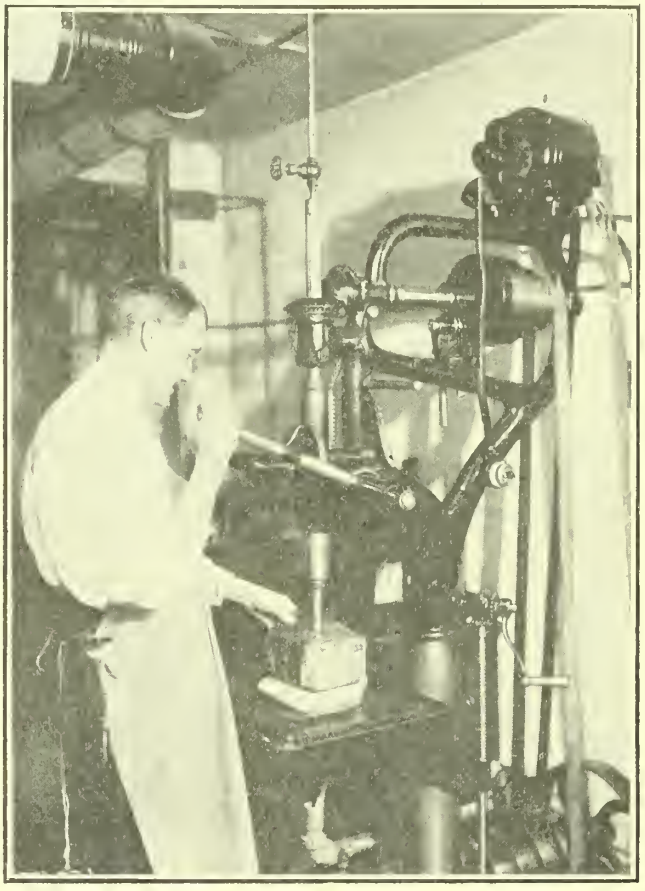
THE many requests which have been received from time to time by the Bureau of Public Roads regarding the proper construction and use of laboratory diamond drills indicates that much difficulty has been experienced by numerous road materials laboratories along these lines. For this reason it has been deemed advisable to publish somewhat in detail the methods used by the Bureau in the manufacture of these drills, and, inasmuch as the life of a drill depends to a very large extent on the way it is used, some precautions regarding their proper use are also given.

Black carbons or diamonds used for laboratory drills should range from $\frac{1}{16}$ inch to $\frac{3}{32}$ inch in size and should be dense and regular in shape. Diamonds suitable for the work will weigh in the neighborhood of 0.1 carat each and from six to eight diamonds are required for a 1-inch drill. They may be obtained from any of the diamond importers.

The diamond drill used by the bureau consists of a steel or bronze crown soldered to the end of a seamless steel tube about $4\frac{1}{2}$ inches long and $1\frac{1}{8}$ inches outside diameter and carrying six diamonds, each about $\frac{3}{32}$ inch in diameter. The other end of the steel tube carries a No. 2 Morse taper hollow drill shank through which water is admitted to the inside of the drill. The drill crown proper is made either of Tobin bronze or soft cold-rolled steel, 1 inch internal diameter, $1\frac{7}{32}$ inches external diameter, $\frac{1}{4}$ inch high, with a recess $\frac{5}{32}$ inch in depth by $1\frac{1}{8}$ inches in diameter in which the steel tube is soldered. A detail view of the drill crown showing the various dimensions is shown on page 24.

SETTING DIAMONDS IN DRILL CROWN.

On the next page are shown the various pieces of apparatus used in the operation of setting the diamonds in the drill crown. *A* is a piece of cold drawn steel $1\frac{1}{4}$ by $\frac{1}{2}$ by 6 inches, with a yoke *C* and thumbscrew and is used to hold the drill crowns. After mounting a crown in the clamp as shown, six holes are drilled in the face of the crown at equal distances apart, three of the holes almost breaking through the outside of the face of the ring and three almost breaking through the inside of the face. The holes should be slightly smaller than the diamonds which are to be used, and each should be slightly nicked on the thin edge with a fine file. A diamond is then placed in one of the holes, gently tapped with a piece of brass so as to hold it in place after which the crown is placed in a small jeweler's vice *D*, having jaws of soft steel or brass, with which the diamond is forced into the hole. Should the diamond not stand the pressure and crumble it is not fit for drilling. It should be possible to force any diamond good enough for drilling purposes into a hole in the above manner. Flat drills *B*, made of $\frac{1}{8}$-inch drill rod, turned about $\frac{1}{2}$ inch long and of a size slightly smaller than the diamonds, are used for drilling the holes. It has been found that the flat drills are better than twist drills for they are stiffer and do away with a center punch. After the diamonds are all set, the drill is soft soldered to the end of the steel tube and is then ready for use.

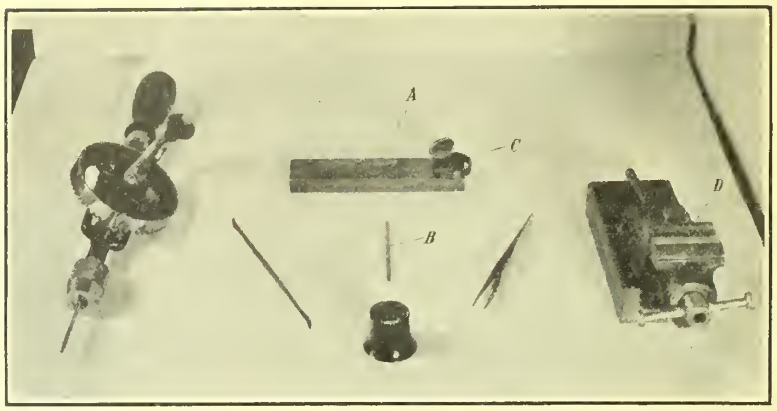


THE DRILL IN USE SHOWING PROPER METHOD OF BEDDING THE SAMPLE.

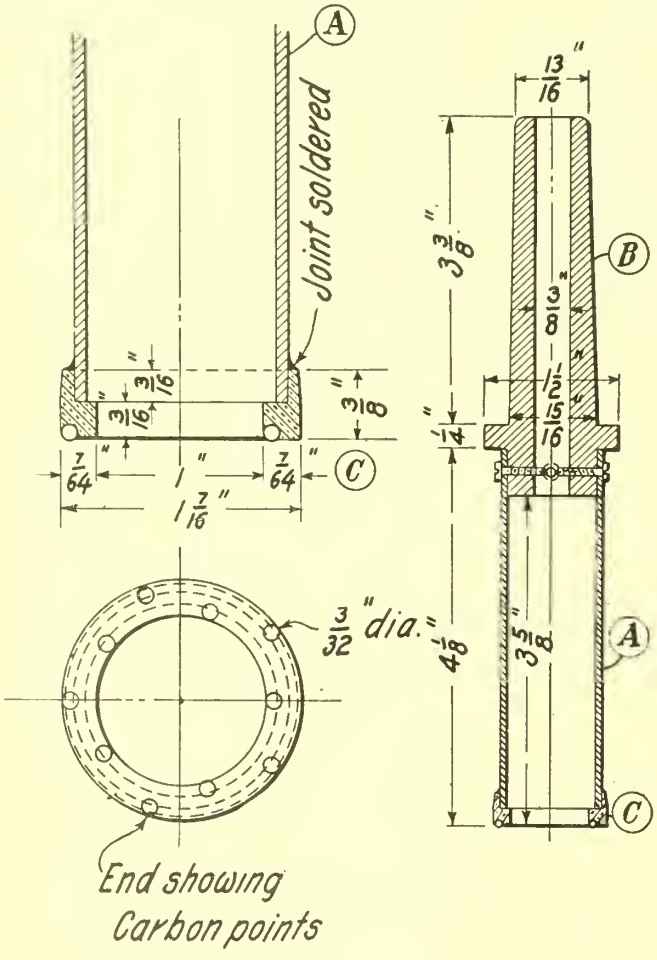
Any drill press equipped with a hollow spindle and with the table so arranged that the water carrying the rock cuttings may be properly collected and carried away is satisfactory for use in rock drilling. A drill press equipped with a No. 2 Morse taper is large enough. The speed of the drill should be about 300 revolutions per minute.

USING THE DIAMOND DRILL.

Great care should be exercised when first using a diamond drill. A block of very soft limestone or sandstone should be selected and a number of cores cut from this stone until it is found that the drill is working properly, after which it may be used on harder rock. The sample should be bedded on a bag filled with sand, as shown on page 23, or in the case of very small pieces it may be necessary to mount the samples in plaster of Paris before drilling. Plenty of water should be used on the inside of the drill so as to keep the space under the crown entirely free from rock cuttings, which, especially in the case of soft rock, have a tendency to "gum up" the drill. After one or two cores have been drilled, their diameter should be measured, and if it is found that the drill is cutting cores more than 25 millimeters or less than 24 millimeters in diameter, one or two of the diamonds must be reset. If the drill crown is turned to the dimensions shown, however, and the diamonds set as indicated, the cores should come out very close to 25 millimeters in diameter. The pressure should be applied always by hand and never automatically on account of the tendency of carbons to shatter if subjected to any appreciable impact. When drilling stone by hand, the pressure on the drill may be regulated in accordance with the character of the material being drilled. This is, of course, not the case if an automatic feed is used. A much greater pressure may be used when drilling fine-grained, homogeneous materials, such as trap, even if the rock is very hard, than in the case of coarse-grained, nonhomogeneous materials or stone in which minerals of greater hardness than the mass of the rock are embedded. With a properly constructed drill, it should be possible to cut a core 4 inches in length from rock of medium hardness in about 10 minutes. The drills made by the Bureau of Public Roads will cut from 20 to 50 feet of rock before it becomes necessary to discard them, depending, of course, on the average hardness of the stone being used.



APPARATUS USED IN SETTING THE DIAMONDS.



DIAMOND CORE DRILL

FIGURE SHOWING DIMENSIONS OF THE DRILL CROWN.

CORRECTIONS.

The jinx was working overtime when the captions were added to the illustrations in our June issue. We do our best to make amends as follows:

Page 5. The caption of the top picture should read: "Bulkhead bridge over the West Walker River, Nev., on Federal-aid project No. 83."

Page 9. The photograph at the left is a view of Pennsylvania Federal-aid project No. 29, from Milford to Matamoras, a bituminous concrete road. At the right is a concrete Federal-aid project, No. 22, from Tobyhanna to Mount Pocono, Pa.

Page 11. The second word of the caption should be "road."

Page 19. The caption should read as follows: "Matchless Crater Lake in Crater Lake National Park. A forest road now under construction will reach this lake."

FEDERAL AID ALLOWANCES.

AT THE close of the fiscal year June 30, 1920, all States with the exception of Oklahoma and South Dakota had entered into agreements with the Secretary of Agriculture for the construction of road projects which will call for the expenditure of their allotments of Federal funds for the fiscal years 1917, 1918, and 1919. The excepted States had not taken up the entire amount of their allotments for the fiscal year 1918, but owing to the fact that during that year they had no recognized State highway departments they are allowed under the law until June 30, 1921, to take up their apportionments for 1918.

Three States, Illinois, Maryland, and Washington, had executed agreements calling for the entire amount of Federal money available to them for each year up to and including the fiscal year 1920; and several other States have submitted plans, specifications, and estimates for projects which will entirely consume their allotments up to the beginning of the current fiscal year.

At the beginning of the new fiscal year, July 1, 1920, 2,984 project statements had been approved representing 29,319.35 miles of Federal-aid road which it is estimated will cost $384,916,819.53 and on which Federal aid to the amount of $163,841,503.93 had been approved.

On the same date project agreements had been entered into for 1,963 projects involving 15,178.08 miles which it is estimated will cost $253,990,389 and for which $109,838,173.71 of Federal aid will be allowed.

PROJECT STATEMENTS APPROVED IN JUNE, 1920.

State.	Project No.	County.	Length, in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	74	Montgomery	11.180	Gravel	June 12	$187,399.08	$93,699.54
Arizona	28	Pinal	7.500	Selected material	...do	185,630.50	90,000.00
Arkansas	92	Grant	4.760	Macadam	...do	30,534.46	14,400.00
	93	Crittenden	8.650	Concrete	June 25	267,953.40	43,000.00
	94	.....do	9.380	Gravel	...do	105,927.25	40,000.00
	95	.....do	8.450	Concrete	...do	307,711.80	73,500.00
	96	Poinsett	4.250	.....do	...do	148,104.00	42,000.00
	100	Mississippi	10.670	.....do	...do	413,163.30	100,000.00
	40	Hempstead	9.510	Gravel	June 8	[1] 63,789.00	[1] 19,000.00
Georgia	157	Pierce	8.900	Sand-clay	June 3	133,608.75	40,000.00
	159	Miller		Bridge	June 4	65,120.00	25,000.00
	136	Brooks and Lowndes		.....do	June 3	48,839.12	24,419.56
	152	Grady		.....do	...do	30,668.00	15,000.00
	153	Newton	9.900	Sand-clay	...do	80,000.80	40,000.00
	154	Wayne	12.000	.....do	...do	79,915.00	39,000.00
	156	Decatur	1.230	.....do	June 12	37,778.40	15,000.00
Iowa	55	Scott	19.330	Earth	June 4	85,052.00	42,500.00
Minnesota	180	St. Louis	1.030	Concrete, brick, or asphalt	June 8	50,481.20	20,600.00
	182	.....do	.990	.....do	June 7	36,119.60	18,059.80
	183	.....do	1.620	.....do	...do	56,944.80	28,472.40
Missouri	118	Stoddard	15.000	Gravel	June 4	126,999.99	63,499.99
	122	Pettis	4.750	Bituminous macadam	June 8	63,000.00	31,500.00
Montana	116	Musselshell		Bridge	June 12	19,453.50	9,726.75
	119	Wheatland	7.250	Earth	...do	64,392.88	32,196.44
	120	Ravalli	6.000	Gravel	...do	33,145.20	16,572.60
	20	Missoula	[1] 7.000	.....do	June 28	[1] 21,985.26	[1] 10,992.63
New Hampshire	107	Merrimack	1.000	.....do	June 3	15,000.00	7,500.00
	92	.....do	.500	.....do	...do	8,000.00	4,000.00
	118	Grafton	.340	.....do	June 7	10,229.98	5,114.99
New York	70	Rockland	3.850	Concrete	June 12	154,000.00	77,000.00
	67	Albany and Schenectady	11.100	.....do	June 11	632,700.00	221,445.00
	69	Delaware	10.570	.....do	June 12	517,300.00	181,055.00
Ohio	144	Allen	6.258	.....do	June 3	290,000.00	75,600.00
	115	Brown	2.794	Macadam	...do	85,000.00	40,000.00
	116	.....do	5.774	.....do	...do	168,000.00	82,500.00
	132	Mahoning	1.750	Brick	...do	79,742.66	26,250.00
	141	Summit	2.270	Concrete and brick	...do	145,810.23	21,000.00
	153	Clermont	6.974	Macadam	...do	240,600.00	120,300.00
South Carolina	43	Sumter	18.181	Sand-clay	...do	137,760.59	25,000.00
	50	Dillon	19.767	.....do	June 8	131,647.94	40,714.39
	78	York	8.066	Top soil	...do	55,353.73	12,000.00
Tennessee	28	McMinn	14.507	Concrete, asphalt, or bituminous macadam	June 3	342,660.50	171,330.25
Texas	145	Tom Green	10.000	Bituminous	June 4	250,548.21	100,000.00
	164	Erath	31.267	Gravel and crushed rock	...do	350,217.99	162,000.00
	163	Childress	10.150	Sand-clay	June 8	70,004.69	35,000.00
	38	Lamar	4.850	Gravel	June 11	172,417.46	86,208.73
	161	Limestone	23.371	.....do	...do	289,611.31	59,400.00
	167	Delta	11.700	.....do	June 25	280,156.06	110,000.00
	19	Eastland	[1] 28.300	.....do	June 3	[1] 117,983.80	[1] 35,000.00
Vermont	16	Washington	1.265	.....do	...do	37,161.24	18,580.62
West Virginia	94	Fayette	5.200	Macadam	June 30	74,565.00	33,480.00
	96	Nicholas	2.210	Earth	...do	49,000.00	24,500.00
	95	Ohio	1.000	Concrete	June 8	45,531.20	13,290.00
Wisconsin	144	Chippewa	3.580	Earth	June 4	41,560.08	20,000.00

[1] Withdrawn.

PROJECT AGREEMENTS EXECUTED IN JUNE, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	39	Madison	7.729	Gravel	June 7	$114,634.58	$57,317.29
	59	Jefferson	5.030	Bituminous concrete on concrete base	June 8	225,694.64	104,087.45
	42	Talladega	5.690	Top soil	June 25	72,499.77	36,249.88
	69	Lamar	10.950	Gravel	June 26	103,885.90	51,942.95
	73	Choctaw	6.311	Sand-clay	...do	66,343.42	33,171.71
	74	Montgomery	11.180	Gravel	June 29	187,399.08	93,699.54
	44	Dale		Bridge	June 28	[1] 30,760.95	[1] 11,997.98
	23	Coffee		Sand-clay	June 25	[1] 40,988.91	[1] 20,494.45
	18	Jefferson	1.920	Bituminous macadam	June 10	[1] 181,333.94	[1] 69,732.32
	12	Lowndes		Sand-clay	June 14	[1] 2,721.40	[1] 1,360.70
	26	Cleburne		Gravel	June 7	[1] 13,176.15	[1] 6,588.08
Arizona	15AB	Gila	18.047	do	June 8	88,734.29	44,367.14
	19A	Yavapai	10.792	do	June 21	104,420.58	52,210.29
	13	Greenlee	5.368	do	June 28	183,241.46	91,620.73
	18ABE&F	Pima and Cochise	16.740	Bridge, and gravel	...do	256,766.76	128,383.37
	21	Coconino	1.098	Concrete or bituminous top on concrete	June 26	68,826.23	25,139.46
	23B	Pinal	5.199	Gravel	June 21	67,403.49	33,701.74
	23ACE&F	do	17.084	Gravel or caliche	June 26	233,744.08	116,872.04
	16	Pinal, Gila	19.978	Broken stone	June 30	1,242,587.92	432,367.92
	8	Maricopa		Concrete and bituminous concrete	June 15	[1] 11,989.23	[1] 5,994.61
Arkansas	60	Yell	31.830	Bituminous macadam	June 5	307,419.42	130,000.00
	26	Johnson	12.920	do	June 30	143,685.45	60,000.00
	38	Sevier and Howard	9.840	Gravel	...do	59,969.73	24,000.00
	43	Lincoln and Desha	2.050	do	...do	22,579.92	7,700.00
	61	Vendor	23.140	do	...do	70,785.73	34,500.00
	69	Conway	5.940	do	...do	58,974.30	12,500.00
	75	Dallas	21.550	do	...do	90,825.54	30,000.00
	76	do	14.070	do	...do	53,996.25	20,000.00
	83	Sevier	8.600	do	...do	35,038.30	17,000.00
	31	Cleveland		do	...do		[1] 15,000.00
California	41	Imperial	14.860	Reinforced concrete	May 24	355,389.46	177,694.73
Colorado	15	Logan	0.651	Concrete	May 29	24,981.28	12,490.64
	32	Adams	5.737	do	June 4	188,717.47	94,358.73
	92	Pueblo		Gravel and bridge	...do	125,224.34	62,612.17
	82	Jefferson	2.017	Concrete	...do	77,990.25	38,995.12
	23	Mesa	5.860	Gravel	...do	64,806.83	32,403.41
	34	Weld	1.568	Concrete	May 29	68,582.47	31,360.00
	43	Yuma	18.061	Earth	...do	61,785.62	30,892.81
	64	Costilla	7.831	do	...do	28,094.84	14,047.42
	35	Weld	1.193	Concrete	...do	48,768.41	23,860.00
	11	Yuma	7.497	Earth	June 14	25,981.86	12,990.93
	41	Logan	0.309	Gravel and bridges	June 11	87,769.25	43,884.62
	78	Eagle	2.758	Earth	...do	113,649.53	55,174.00
	83	Arapahoe	2.699	Concrete	June 14	108,790.71	53,980.00
	91A	Las Animas	5.651	Gravel	...do	73,352.01	36,676.00
Connecticut	4	Hartford, Tolland, New London.	32.186	Concrete	June 16	1,835,264.71	643,720.00
Florida	11	Duval Nassau and Baker	15.400	Brick Grouted on sand foundation	June 23	706,379.48	320,876.97
	21A	Baker	5.680	Cement grouted brick on sand foundation	June 25	247,174.54	113,600.00
	22	do	8.900	do	...do	362,259.16	178,000.00
	23	Duval	12.800	do	...do	583,142.12	258,576.06
	24	Columbia	9.890	do	...do	400,946.12	197,800.00
Georgia	70	Morgan	7.386	Concrete	June 24	253,167.51	121,000.00
	122	Grady		Bridge	...do	23,051.65	11,525.82
	81	Dougherty		do	June 7	295,574.40	110,000.00
Idaho	9	Adams and Idaho	20.680	Earth	June 29	670,095.65	335,047.82
	11	Elmore	26.580	Gravel	June 21	269,969.00	134,984.50
	5	Lemhi		Earth and gravel	June 26	[1] 70,121.96	[1] 43,288.08
Iowa	33	Clarke	8.450	Earth	June 3	65,269.60	32,600.00
	65A	Boone	11.510	Gravel	...do	103,899.84	36,200.00
Kansas	35 ABC	Summer	8.535	Concrete	June 22	369,689.59	128,025.00
	51	Franklin	0.835	Concrete or bituminous filled brick mono	June 19	61,559.27	6,000.00
	44	Saline	5.250	Brick or concrete	June 22	358,540.41	78,750.00
	45	do	7.015	Mono brick or concrete	...do	460,633.61	105,225.00
Kentucky	13	Carter	15.039	Earth	June 30	176,032.95	88,016.47
	17	Clark	6.017	Rock asphalt	...do	233,032.95	116,516.47
	23A&B	Whitley	6.545	Brick on concrete base and rock asphalt on macadam.	...do	176,671.12	67,913.07
	24	Jessamine	6.969	Surface-treated macadam	...do	124,041.41	62,020.70
	26	Jefferson	11.143	Rock asphalt on macadam	...do	593,280.64	239,655.00
	29A	Laurel	1.287	do	...do	67,649.39	25,740.00
	15	Boone and Kenton	2.108	Concrete	June 25	97,422.12	42,160.00
	21A	Bell	5.245	Rock asphalt	...do	126,736.57	63,368.28
	20	Breathitt	6.535	Earth	June 26	236,057.17	118,028.58
	10	Larue	3.348	Waterbound macadam		[1] 69,993.11	[1] 34,996.55
	3	Rowan		Earth	June 30	[1] 261,768.80	[1] 123,933.16
Maine	8	Waldo	2.540	Bituminous macadam	June 16	122,788.17	61,394.08
	9	Cumberland	4.720	Concrete	...do	244,369.52	101,748.13
	19	Franklin	2.690	Gravel	...do	63,327.44	31,663.72
	26	Cumberland	3.920	Bituminous macadam	...do	109,891.57	54,945.78
	10	do	2.520	Concrete	...do	113,282.88	50,400.00
	11	do	7.080	do	...do	322,357.83	146,572.99
	14	Penobscott	4.710	Bituminous macadam	...do	184,842.57	92,421.28
	18	Franklin	3.880	Gravel	...do	102,429.47	51,214.73
Massachusetts	21	Berkshire	3.637	Concrete	June 21	167,178.00	72,740.00
	13	Middlesex	6.450	do	June 29	289,550.14	130,504.25
	22	Franklin	6.430	Bituminous concrete and gravel	...do	115,039.43	57,519.71
	29	Hampshire	2.626	Bituminous macadam	...do	93,115.11	46,557.55
	32	do	3.078	do	...do	173,896.52	86,948.26
	33A	Middlesex	2.182	do	...do	94,446.00	43,640.00
	37	Berkshire	1.164	do	...do	41,158.15	20,579.07
	38	Essex	2.827	Bituminous macadam and concrete	...do	151,589.35	56,540.00
Michigan	35	Washtenaw and Jackson	25.157	Bituminous concrete on concrete	June 12	1,071,097.33	503,140.00
	38	St. Clair	16.594	Concrete	...do	740,789.30	370,394.65
	42	Wayne	14.211	do	...do	573,196.89	284,220.00
Minnesota	116	Sibley	1.080	Gravel	June 7	57,667.83	21,600.00
	78	Yellow Medicine	14.030	do	June 8	57,195.69	20,000.00
	82	Pipestone	9.703	Concrete	June 3	353,389.64	100,000.00
Mississippi	49	Coahoma	10.660	do	June 14	319,877.77	100,000.00
	75	Chickasaw	5.680	Gravel	...do	72,900.99	36,450.49
	93	Pearl River	12.980	do	...do	114,341.00	57,170.50
	32	Lee	15.420	Concrete	June 26	565,587.61	282,793.80
	48	Yazoo	3.928	do	...do	131,819.18	65,909.59
	61	Sharkey	13.060	do	June 28	249,172.07	100,000.00
	20	Walthall		Gravel	June 14	[1] 22,934.88	[1] 11,606.75
Missouri	24	Cooper	5.570	Bituminous macadam	June 9	88,554.82	44,277.41
	27	do	7.835	do	...do	129,409.96	64,704.98
	53	Lawrence	21.060	Gravel	...do	101,714.39	50,857.19

PROJECT AGREEMENTS EXECUTED IN JUNE, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Missouri	61	Jackson	2.100	Earth	June 9	$136,493.17	$52,883.15
	78	St. Louis	6.070	Concrete and hillside brick	do	304,539.32	126,270.20
	79	St. Louis	12.680	Asphalt, concrete, and hillside brick	do	649,249.23	257,970.64
	94	Buchanan	.376	Asphalt, concrete	do	29,892.11	7,520.00
	36	Christian	9.306	Gravel and concrete	June 24	65,418.17	32,709.08
	52	Cape Girardeau	3.180	Concrete	June 9	102,523.67	51,261.83
	39	Lewis	7.935	Gravel	June 23	96,067.97	48,033.98
	54	Gentry	8.857	Bituminous macadam	do	181,536.64	90,768.32
	60	Lewis	5.800	Gravel on macadam	do	88,637.80	44,318.90
	62	Marion	10.260	Gravel	do	81,502.80	40,751.40
	68	Lewis	4.281	do	do	50,127.45	25,063.72
	77	St. Louis	15.762	Concrete and hillside brick	do	688,325.88	329,068.82
	80	do	7.026	Concrete	do	303,000.69	144,928.43
	81	Jasper	2.760	do	do	95,373.75	47,686.87
	26	Dunklin	8.620	Gravel	do	118,016.27	59,008.13
	18	Jackson		Bituminous macadam	do	[1] 21,101.78	[1] 10,550.89
	23	Pettis		do	do	[1] 7,290.70	[1] 3,645.35
Montana	70A	Silver Bow	9.110	Paving	May 21	335,877.10	167,938.55
	14	Park		Bridge	June 8	55,049.50	27,524.75
	15	Rosebud	3.560	Gravel	June 15	21,767.07	10,883.53
	61	Wibaux	6.860	do	June 24	35,732.16	17,866.08
	9B	Madison	4.580	Selected material	June 25	25,286.77	12,643.38
	44	Gallatin	4.924	Concrete	June 28	206,966.06	98,480.00
	49	Meagher	20.280	Earth	do	150,216.79	75,108.39
	51	Gallatin	.840	Concrete	do	68,759.08	16,800.00
	63	Missoula	19.611	Gravel	do	133,976.55	66,988.27
	64	Cascade	18.260	do	do	259,409.49	129,704.74
	83	Valley	1,890	do	June 18	16,717.71	8,358.85
	100	Flathead	3.210	do	June 28	31,581.33	15,790.66
	101	Blaine	10.800	do	do	51,805.00	25,902.50
	106	Carbon	11.630	do	do	97,624.89	48,812.44
	57	Yellowstone	1.039	Concrete	June 30	52,764.85	20,790.00
	68	Deer Lodge	9,376	do	do	333,465.28	166,732.64
	53A	Yellowstone		Gravel	May 21	[1] 56,291.70	[1] 28,145.85
	20	Missoula	[2] 6.870	do	June 28	[2] 21,993.54	[2] 10,996.77
	40	Gallatin		do	do	[1] 3,153.69	[1] 1,576.84
	8	Meagher		do	do	[1] 11,960.26	[1] 5,980.13
	69	Jefferson	.703	Bituminous concrete, or concrete	June 30	27,716.14	13,858.07
	93	Flathead	3.380	Gravel	June 29	21,474.72	10,737.36
	29	Missoula	1.313	Earth and gravel	June 30	56,630.83	26,260.00
	33	Musselshell	4.350	Gravel	do	21,993.34	10,996.67
	52	Yellowstone	1.995	Concrete	do	94,876.70	39,900.00
	54	Cascade		Gravel	do	[1] 2,744.94	[1] 1,372.47
	92	Granite	6.664	Earth	do	98,514.48	50,860.49
Nebraska	135A	Merrick	9.330	Gravel	May 13	47,627.27	23,813.63
Nevada	23	Mineral	9.330	Earth	June 7	183,357.90	91,678.95
	27	Clarke		Bridge	do	87,407.10	43,703.55
	30	Ormsby	3.490	Concrete	do	126,177.19	63,088.59
	29A & B	Washoe	10.480	do	do	414,915.29	207,457.64
	19	Pershing	27,810	Gravel	June 30	103,718.21	51,859.10
	7	Washoe		Concrete	June 20	[3] 112,091.73	[3] 55,488.23
New Mexico	14B	Santa Fe	8.258	Earth	June 3	48,184.68	24,092.34
	13A	Valencia	10.859	Crushed stone	June 24	82,789.92	41,394.96
	24	Roosevelt	11.365	Caliche, two course	June 22	88,321.51	44,160.75
	39	Quay		Bridge	June 14	130,459.03	65,229.51
	25	Curry	15.437	Caliche	June 23	153,992.71	76,996.35
	32	San Miguel	15.084	Crushed stone	do	157,970.20	78,985.10
	47	Grant	15.228	Gravel	do	116,120.63	58,060.31
	33	Moro	12.705	do	do	190,989.67	95,494.83
	11	Lincoln		do	June 3	[3] 4,814.19	[3] 2,407.09
New York	33	Schoharie	10.330	Reinforced concrete	June 11	412,983.67	144,544.28
	39	Tioga	7.250	do	do	289,905.86	144,952.93
	43	Clinton	7.900	do	do	316,000.00	158,000.00
	44	Genesee	2.710	do	do	108,400.00	54,200.00
	53	Jefferson	3.250	do	June 12	121,500.00	42,525.00
	63	Tompkins	4.470	do	June 15	177,400.00	62,090.00
	59	Onondaga	3.940	do	do	157,600.00	78,800.00
	65	Otsego and Schoharie	10.580	do	do	423,200.00	151,013.50
	14A & B	Chautauqua	7.630	do	June 22	305,200.00	152,600.00
	31	Schuyler and Seneca	11.430	do	June 15	433,997.95	221,998.97
	32	Fulton and Saratoga	11.310	do	June 21	449,500.00	195,470.00
	41	Orleans	2.050	do	June 15	82,000.00	28,700.00
	58	Chemung and Tioga	3.620	do	do	144,800.00	72,400.00
	60	Herkimer	1.090	do	do	43,600.00	21,800.00
	11	Orange	2.580	do	June 24	103,200.00	51,600.00
	13	Chautauqua	6.500	do	do	260,000.00	130,000.00
	22	Broome	4.090	do	do	215,000.00	75,250.00
	35	Jefferson	8.370	do	do	334,800.00	167,400.00
	40	Oswego	9.370	do	do	356,600.00	124,810.00
	46	Dutchess	2.480	Bituminous macadam	do	114,900.00	40,215.00
	69	Delaware	10.570	Reinforced concrete	do	517,300.00	181,055.00
	37	Jefferson	2.610	do	June 25	90,700.00	31,745.00
	19	Franklin	2.840	do	June 28	113,600.00	56,800.00
	48	Wayne	1.790	do	June 29	71,600.00	35,800.00
	54	Madison	5.990	Concrete	do	239,600.00	119,800.00
	57	Genesee	2.100	Reinforced concrete	June 28	78,500.00	27,475.00
	61	Livingston	5.180	do	do	211,100.00	73,885.00
	26	Steuben	2.780	do	June 29	111,200.00	55,600.00
	47	Delaware	12.540	do	do	633,400.00	221,690.00
	49	Wayne	.990	do	do	39,600.00	19,800.00
	16	Ontario and Wayne	6.990	do	do	279,600.00	139,800.00
North Dakota	39A	Grant	6.000	Earth	June 4	32,562.63	16,281.31
	100	Burleigh and Morton		Concrete	June 15	876,000.00	438,000.00
	64	Logan		Bridge	do	3,858.50	1,929.25
	22	Towner	17.489	Earth	June 29	75,820.47	37,910.23
	36A	Baines	14.250	do	do	61,708.55	30,854.27
	19	Ramsey		do	June 30	[3] 30,153.05	[3] 15,076.53
	44	Bottineau		do	June 20	[1] 5,590.41	[1] 2,795.21
	18	Ramsey		Gravel	June 28	[3] 15,218.72	[3] 7,609.36
	16	Grand Forks		do	June 21	[1] 37,519.71	[1] 18,759.85
Ohio	44	Lorain	2.688	Brick, bitumen, or reinforced concrete	May 21	129,000.00	50,000.00
	63	Hamilton	2.723	Concrete, semimono brick, warrenite, bitulithic, or bitolslag	do	163,000.00	54,400.00
	75	Belmont	3.839	Bituminous macadam	June 24	139,200.00	40,000.00
	79	Fulton	6.191	Concrete	June 8	206,000.00	80,000.00
	118	Wood	3.378	Reinforced concrete or bituminous concrete	June 24	177,100.00	20,000.00
	138	Clermont	4.821	Water-bound or bituminous macadam	June 8	154,700.00	70,000.00

PROJECT AGREEMENTS EXECUTED IN JUNE, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Oklahoma	17	Canadian and Grady		Bridge	June 2	$294,135.38	$147,067.69
	18	Muskogee	29.533	Gravel	June 17	408,741.32	204,370.66
Oregon	36	Wasco	7.750	Earth	June 1	76,958.64	38,479.32
South Carolina	81	Charleston	7.384	Concrete	June 3	325,931.99	78,488.26
	28	Orangeburg	20.241	Cement and sand-clay	June 17	376,631.88	125,614.93
	84	Laurens	14.131	Top soil	do	84,731.87	32,301.06
	94	Union	3.873	do	do	23,521.89	4,200.00
South Dakota	34	Spink	10.880	Gravel	June 2	136,922.10	68,461.05
	26	Kingsbury	14.110	do	June 23	140,712.29	70,356.14
	33	Miner	11.518	do	do	125,422.73	62,711.36
Tennessee	32	Lauderdale	7.717	Bituminous macadam	June 3	268,735.02	134,367.51
	33	Crockett	5.666	do	do	172,012.30	86,006.15
	42	Hamblen	8.314	do	do	169,013.31	84,506.65
	43	Shelby	7.429	do	do	172,501.28	86,250.64
	27	Lewis and Lawrence	20.466	Earth	June 15	88,282.92	44,141.46
	14	Grainger, Hawkins, and Sullivan.	50.129	Bituminous macadam	June 24	1,216,367.13	608,183.56
	26	Maury	11.872	Rock asphalt	do	443,277.85	221,638.92
	35	Hamilton	10.143	Concrete	do	374,348.32	187,174.16
Texas	117	Denton	10.034	Gravel surface treated	June 7	198,754.52	75,000.00
	90	Taylor	19.925	Gravel	June 19	114,781.52	40,030.00
	100	Rockwall	13.360	Concrete	do	570,620.60	200,000.00
	104	Sabine	13.690	Gravel	do	187,384.35	85,000.00
	112	Bexar	7.236	Gravel surface treated	do	77,830.50	35,802.33
	113	Hill	22.810	do	do	458,168.47	124,000.00
	132A	Parker	15.066	do	do	257,819.14	100,000.00
	137	Limestone	28.329	Earth and crushed limestone	do	339,302.75	92,600.00
	82	Jasper	16.210	Gravel and earth	June 21	146,711.71	30,000.00
	128A	Montague	7.472	Sand clay	June 19	56,456.14	20,000.00
	135AB	Schliecher	7.430	Stone macadam	June 22	137,385.58	68,692.79
	154	Bastrop	2.260	Gravel	June 21	20,761.38	10,270.00
	156	Titus	5.150	do	June 22	42,684.04	21,000.00
	92	Hood	27.540	Earth	June 21	180,132.07	70,000.00
	111	Scurry, Mitchell, and Nolan.	21.523	Gravel	June 30	137,131.61	67,150.00
	125	Liberty	8.518	do	June 21	149,257.18	65,000.00
	57	Wilbarder	[2] 2.066	Concrete	June 4	[4] 10,605.17	
	31	Bexar		Gravel and gravel surface treated	June 21	[1] 50,515.94	[1] 25,257.97
	59	Calhoun		Gravel	June 26	[1] 7,173.53	[1] 2,790.00
	117	Benton		Gravel surfaces treated	June 29	[1] 27,274.30	[1] 25,000.00
	131	Bexar	15.767	Concrete-asphalt top; gravel-bitumen top	June 22	204,031.83	81,078.81
	138	Limestone	11.917	Limestone macadam	June 21	192,680.87	48,000.00
	140A	Williamson		Bridge	do	24,851.81	10,000.00
	149	Orange	10.260	Concrete	do	422,683.52	200,000.00
	143	Denton	8.000	Gravel and bitumen top	June 28	204,294.58	100,000.00
	43	Tarrant	5.857	Concrete	June 30	309,391.62	116,000.00
	120	Cass	12.638	Gravel	June 29	122,513.08	37,487.04
	99	Calhoun	4.616	Mudshell on gravel base	June 26	14,180.21	6,500.00
	115	Smith	8.720	Concrete and gravel	June 29	175,955.11	87,257.24
	118	Webb	17.500	Gravel	do	166,570.78	41,507.12
	132B	Parker	16.590	Gravel, bitumen top	June 28	427,441.48	140,000.00
	148	Kleberg	18.600	Gravel	June 29	388,962.58	125,000.00
	151	Bee	21.617	Gravel, bitumen top	do	424,192.72	200,000.00
	86B	Montague	8.090	Gravel	do	104,202.41	51,200.00
	21	Gregg		Surface-treated macadam	June 30	[1] 28,666.67	14,333.33
Utah	9GHJK	Millard	23.670	Concrete	June 4	553,596.88	276,798.44
	4CDE	Carbon and Emery	30.530	Earth	June 16	317,044.11	158,522.05
Vermont	3	Caledonia	.730	Waterbound macadam	June 21	28,776.66	14,388.33
	5	Franklin	.710	do	do	17,003.91	8,501.95
	12	Bennington and Rutland	13.570	Gravel	do	287,118.48	143,559.24
	13	Addison	4.070	Waterbound macadam	do	117,688.23	58,844.11
	14	Windham	5.600	Gravel	June 23	149,536.42	74,768.21
	15	Chittenden	4.030	Bituminous macadam	do	153,787.37	76,893.68
	16	Washington	1.260	Gravel	do	41,980.73	20,990.36
	6	Orange		Bituminous macadam	June 22	[1] 6,619.03	[1] 3,309.52
Washington	35	Whitman	21.370	Crushed rock	May 13	297,899.21	148,949.60
West Virginia	66A	Wirt	2.582	Earth	June 28	39,625.00	19,812.50
Wisconsin	107	Monroe	.880	Concrete	June 22	36,000.99	14,000.50
	135	Buffalo	1.950	do	do	88,999.49	33,500.00
	61	Sauk	.760	Gravel	June 24	25,992.67	9,000.00
	111	Eau Claire	1.900	Concrete	do	83,183.25	28,253.00
	133	Waushara	2.319	Sand-clay	do	18,436.57	7,000.00
	150	Dodge	6.450	Concrete	do	260,422.44	91,212.00
	159	Washington	1.710	do	do	60,236.22	20,750.00
	164	La Crosse	2.100	do	do	89,045.96	33,000.00
	104	Ozaukee	2.460	do	do	100,563.48	30,759.29
	108	Juneau	1.630	Earth	do	27,951.63	11,547.00
	110	Waukesha	3.040	Concrete	do	96,054.81	31,000.00
	113	Douglas	5.795	do	do	283,417.17	95,275.97
	115	Walworth	4.720	do	do	197,812.41	77,465.00
	118	Ashland	1.400	Gravel	do	19,859.51	7,000.00
	123	Manitowoc	3.880	Concrete	do	132,437.50	44,650.00
	139	Brown	2.910	do	do	97,954.05	30,000.00
	153	Eau Claire	.444	do	do	17,219.40	5,800.00
	31	Taylor		Earth	June 22		[1] 3,890.68
	54	Adams		Sand-clay	do		[1] 4,222.70
	72	Jefferson and Dodge		Concrete	June 24	[1] 107,582.99	[1] 37,194.33
	157	Green Lake	.610	do	do	22,903.29	8,434.34
	161	Juneau	.935	do	do	30,208.09	10,086.83
	170	Oneida	4.660	Gravel	do	45,329.87	15,300.00
	171	Richland		Concrete bridge	do	28,139.27	10,427.07
	173	Rusk	1.020	Earth	do	9,315.03	3,300.96
	143	Calumet	4.820	Concrete	do	162,000.00	54,000.00
	162	Kenosha	3.010	do	do	122,137.68	43,388.00
Wyoming	68	Hot Springs	4.281	Selected material	June 15	54,133.75	27,066.87
	45	Albany	2.705	Gravel	do	27,501.85	13,750.92
	55	Uinta	4.012	do	do	27,307.41	13,653.70
	60	Carbon	2.384	do	do	16,567.21	8,283.60
	69	Johnson	10.750	do	do	92,169.57	46,084.78
	40	Niobrara	11.894	Selected material	do	27,118.74	13,559.37
	53	Hot Springs	.959	Gravel	do	36,395.26	18,197.63
	56	Converse	7.169	do	do	66,350.47	33,175.23
	78	Fremont	9.238	Selected material	do	81,561.54	40,780.77
	17	Uinta		Sand-clay	do	[1] 23,894.75	[1] 11,947.37

[1] Modified agreements. Amounts given are increases over those in the original agreements.
[2] Canceled.
[3] Modified agreements. Second revision. Increase.
[4] Modified agreements. Amounts given are decreases from those in the original agreements.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
249. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States, 1914. A Summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
463. Earth, Sand-Clay, and Gravel Roads.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
691. Typical Specifications for Bituminous Road Materials.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and Classification of Rocks for Road Building, Including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
77. Experimental Roads in the Vicinity of Washington, D. C.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 5, D-12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

LIBRARY

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 28 WASHINGTON, D. C. AUGUST, 1920

PENNSYLVANIA FEDERAL-AID PROJECT NO. 21. A REINFORCED CONCRETE ROAD NEAR READING

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Soil Pressure Cell Measures Accurately to Tenth of Pound 3
A. T. Goldbeck.

Illinois Builds Roads Despite Shortage 6

Shifting Sand Stopped with Oil on Oregon Federal-Aid Projects . . . 7
A. F. Morris.

Motor Trucks on Eastern Farms 9

British Road Conditions and Highway Administration 10

Wisconsin's Maintenance Policy 17

Valuable Study of Movement of Capillary Water in Soil 18

Maintenance on English Roads 19

Pennsylvania 1920 Automobile Registrations 19

Educational Conference on Highways and Transportation 20

Bureau Assists in Car Allocation 20

Federal-Aid Allowances 21

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer

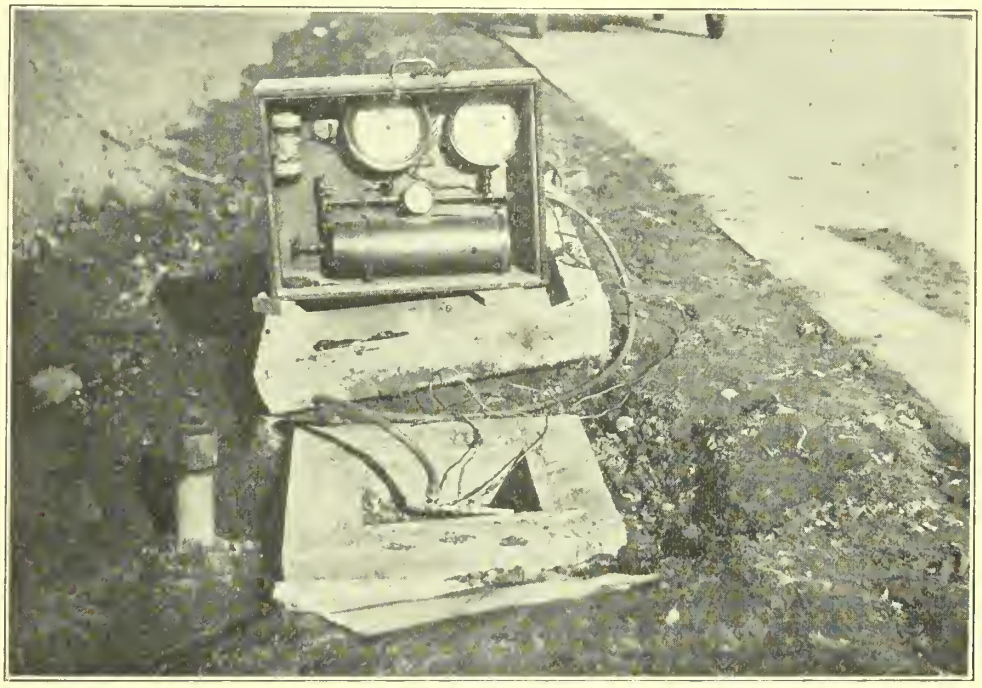
ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

SOIL PRESSURE CELL MEASURES ACCURATELY TO TENTH OF POUND

By A. T. GOLDBECK, Engineer of Tests, Bureau of Public Roads.

THE soil pressure cell referred to in this article was developed by the writer in collaboration with Mr. E. B. Smith, senior assistant testing engineer, and others connected with the laboratories of the Bureau of Public Roads.

Numerous applications of the device have been made in connection with the experimental work of the bureau, such as the determination of the distribution of concentrated loads through sand fills,[1] the measurement of the pressure of concrete against forms,[2] the measurement of the pressures transmitted through road surfaces to subgrades,[3] and the measurement of pressures exerted upon retaining walls.



GENERAL VIEW OF INDICATING APPARATUS, SHOWING HOSE CONNECTIONS TO THE SOIL PRESSURE CELLS BURIED UNDER A CONCRETE ROAD.

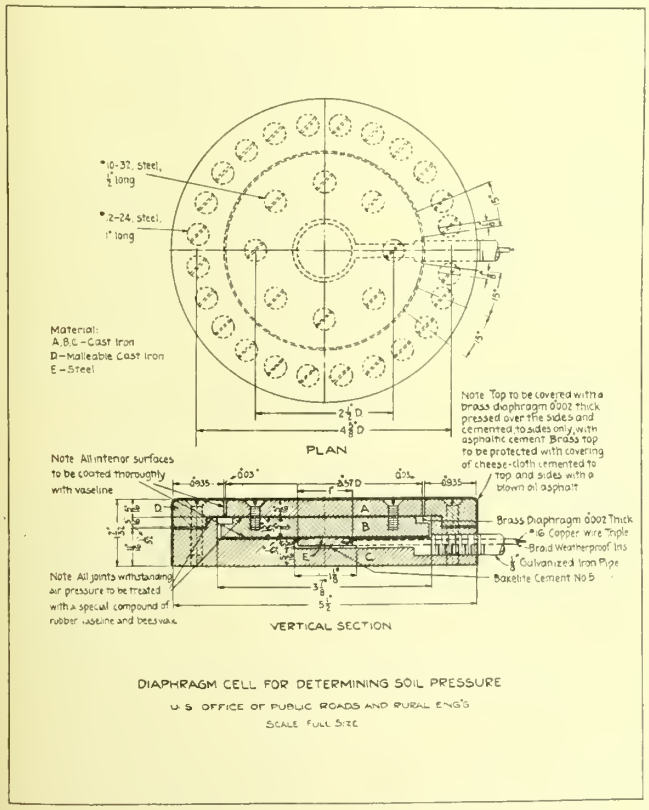

*10-32, steel, ⅛ long
*2-24, steel, 1" long
Material:
A, B, C – Cast Iron
D – Malleable Cast Iron
E – Steel
PLAN
Note. Top to be covered with a brass diaphragm .002 thick pressed over the sides and cemented to sides only, with asphaltic cement. Brass top to be protected with covering of cheese-cloth cemented to top and sides with a brown oil asphalt
Note. All interior surfaces to be coated thoroughly with vaseline
Brass Diaphragm .002 Thick
*16 Copper wire Triple Braid Weatherproof Ins
⅛ Galvanized Iron Pipe
Bakelite Cement No 5
Note. All joints withstanding air pressure to be treated with a special compound of rubber, vaseline and beeswax
VERTICAL SECTION
DIAPHRAGM CELL FOR DETERMINING SOIL PRESSURE
U S OFFICE OF PUBLIC ROADS AND RURAL ENG'G
SCALE FULL SIZE

FIG. 1.—DIAPHRAGM CELL FOR DETERMINING SOIL PRESSURE.

At the suggestion of Mr. Charles H. Paul, assistant chief engineer of the Miami conservancy district, the bureau, in cooperation with the Miami conservancy district, conducted an extensive series of tests to determine the pressure exerted by a hydraulic fill, the tests being made in a standpipe 41 feet in height and 30 inches in diameter.[4] The device has since been adopted by the conservancy district to measure the pressures in their hydraulic fill dams, with results that follow very closely the typical curves resulting from the tests conducted by the bureau.[5] The results of these tests have demonstrated that material such as is used in the core of a hydraulic fill dam acts as a perfect fluid during the early stages of settlement, but that it loses its fluid qualities as consolidation proceeds.

In a paper on "Hydraulic Fill Dams" presented before the American Society of Civil Engineers on May 5, 1920, Mr. Allen Hazen refers to the use of this apparatus by the Miami conservancy district, and raises a question as to the accuracy of the instrument.

[1] The Distribution of Pressures through Earth Fills, Vol. XVII, 1917 Proceedings of A. S. T. M.
[2] Public Roads, Vol. 2, No. 23, March, 1920.
[3] Public Roads, Vol. 1, No. 12, April, 1919.
[4] Tests to Determine Pressures due to Hydraulic Fills, Engineering News-Record, Apr. 18, 1918, p. 758.
[5] Study of Pressures in Hydraulic Dam Cores, Engineering News-Record, Dec. 25, 1919.

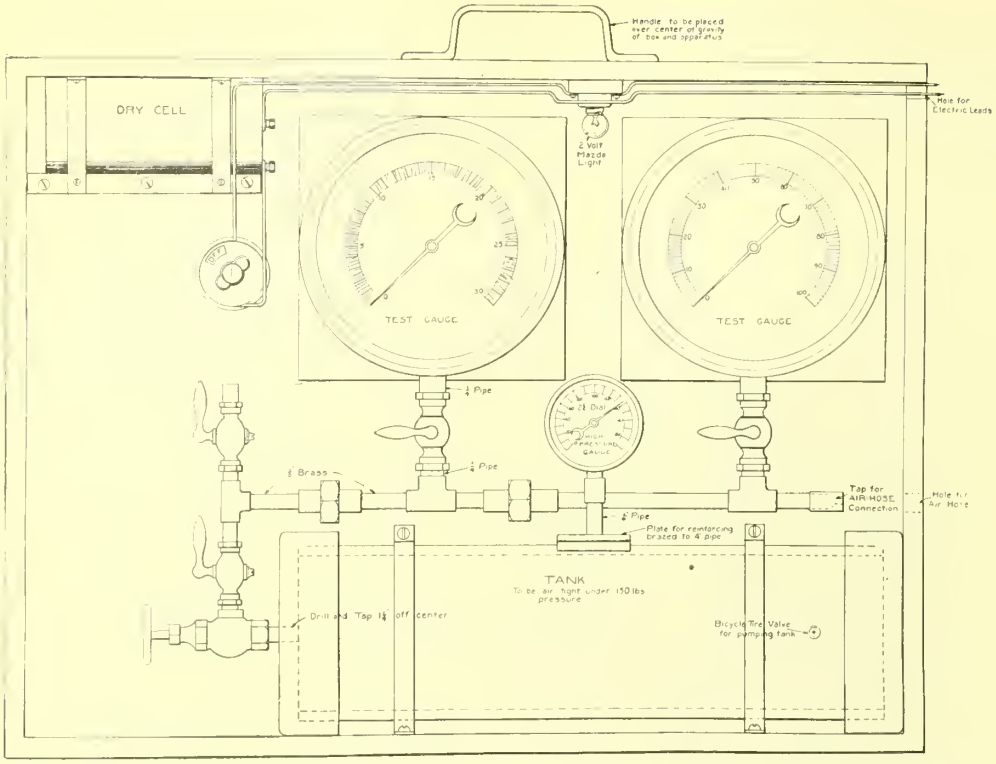

Handle to be placed over center of gravity of box and apparatus
DRY CELL
Hole for Electric Leads
2 Volt Mazda Light
TEST GAUGE
TEST GAUGE
¼ Pipe
¼ Brass
¼ Pipe
¼ Pipe
Tap for AIR HOSE Connection
Plate for reinforcing brazed to ¼ pipe
TANK
To be air tight under 150 lbs pressure
Drill and Tap 1½ off center
Bicycle Tire Valve for pumping tank

FIG. 2.—MOUNTING OF SOIL PRESSURE INDICATING APPARATUS FOR USE WITH DIAPHRAGM CELLS.

For the benefit of those who are not familiar with the soil pressure cell mentioned by Mr. Hazen, it may be well to describe the instrument and its applications before entering upon a description of the tests which confirm its accuracy.

The measurement of pressures transmitted through granular materials has always been a difficult one, primarily due to the fact that the measuring instrument must be capable of indicating such pressures with but an infinitesimal movement of the instrument itself The slightest motion of the weighing face disturbs the soil so that the pressure originally existing may be changed considerably at the instant the measurement is made. Any instrument to be successful for this purpose must be capable of measuring pressures with practically no motion and the soil pressure cell mentioned by Mr. Hazen fulfills this requirement.

PRINCIPLE OF ACTION.

The principle of its action may best be understood by referring to the cross section drawing shown in figure 1. The underlying idea of the device is to equilibrate the external earth pressure on the weighing face by means of internal air pressure, detecting the instant at which equilibration takes place through the breaking of an electrical circuit within the instrument and at that instant noting the air pressure required to overbalance the earth pressure.

Referring to figure 1, the soil-pressure cell is seen to consist of a cast-iron base C, $5\frac{1}{2}$ inches in diameter, in the center of which is cemented a steel button E. Bakelite cement is used for this purpose for the double reason that it is an insulator as well as a cement. A thin brass diaphragm, as thin and flexible as a sheet of paper,is stretched across the base C and is held in place by the malleable cast-iron ring D. This diaphragm is clamped between two cast-iron disks, A and B, the lower disk, B, bearing on the button E. To protect the cell from moisture and to prevent the small annular space between ring D and disk A from becoming clogged with soil, the top of the cell is covered with a brass diaphragm like that between disks A and B, and the entire instrument is coated with a layer of cheesecloth cemented with a blown-oil asphalt. Blown oil is used for this purpose because of its comparative nonsusceptibility to temperature change. A galvanized-iron pipe connects the pressure cell with a small tank of compressed air which is placed in a portable indicating box containing pressure gauges for reading the air pressure within the cell. An insulated electric wire is led through this pipe to the button E, and the pipe itself furnishes the return circuit. A small dry cell and a miniature electric light are the only other electrical equipment required.

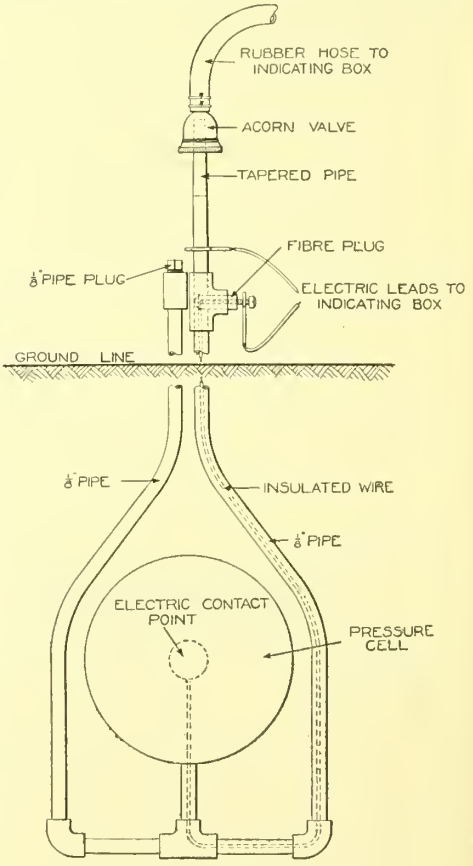


FIG. 3.—PIPE AND ELECTRICAL CONNECTIONS OF SOIL PRESSURE CELL.

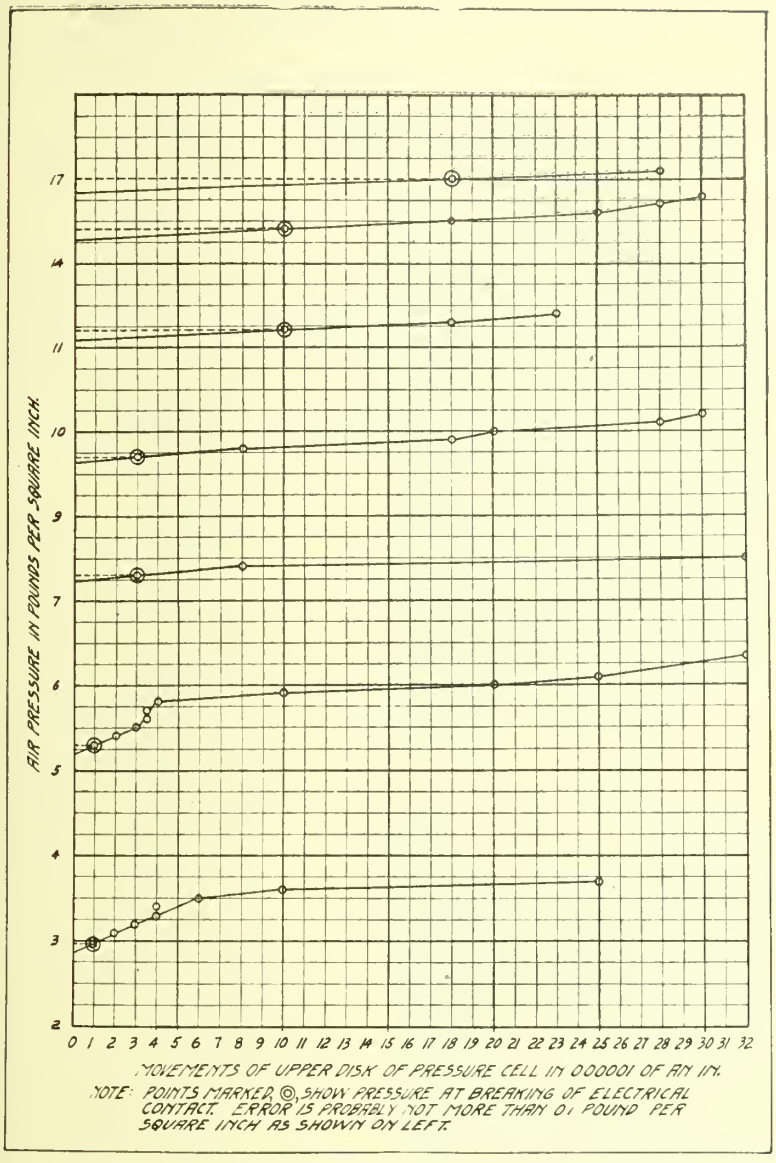

AIR PRESSURE IN POUNDS PER SQUARE INCH
17
14
11
10
9
7
6
5
4
3
2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
MOVEMENTS OF UPPER DISK OF PRESSURE CELL IN 0.0001 OF AN INCH.
NOTE: POINTS MARKED ◎ SHOW PRESSURE AT BREAKING OF ELECTRICAL CONTACT. ERROR IS PROBABLY NOT MORE THAN 0.1 POUND PER SQUARE INCH AS SHOWN ON LEFT.

FIG. 4.—CURVES SHOWING MOVEMENT OF UPPER DISK OF SOIL PRESSURE CELL AFTER BREAKING ELECTRICAL CONTACT. CELLS BURIED IN 30-INCH MOIST SAND FILL.

The indicating box used with this pressure cell is shown in figure 2 and in the photograph on page 3. Control valves are also placed in the air line, which very delicately regulate the flow of air from the tank into the pressure cell.

METHOD OF MEASURING PRESSURES.

Let it be supposed that this instrument is to be used for measuring the pressures back of a retaining wall. The cells are first mounted securely against the wall with their weighing face placed toward the earth fill. It is, of course, necessary to mount the cells before the fill is in place. The pipe connections are led up to an accessible position, and if the cells are to remain in place and the readings continued over a long period, it is desirable to use a double pipe connection as shown in figure 3. Should any water collect in the pipes through condensation or leakage, this fact can be determined very readily merely by allowing the air to flow into one side of the pipe line, the other end being open. If water is present pressure will be indicated in the air line, due to the head of water. The mere fact that water is present, however, does not necessarily spoil the readings of the apparatus for, by the use of a double pipe line, the operator can cause the water to mount into one side of the line while he is taking his readings, which are thus not impaired by the presence of the water.

The operation in taking readings is to open the control valve on the pressure tank, thus allowing the air to flow very slowly into the pressure cell. As long as the cast-iron disk *B* in figure 1 is in contact with steel button *E*, this fact will be indicated by the burning of the small electric light in the indicating box. At the instant, however, that the air pressure within the cell slightly exceeds the soil pressure acting on the outside of the cell an exceedingly small movement of plate *B* takes place and it is raised out of contact with steel button *E;* the electric light is extinguished and the operator immediately reads the pressure on one of the test gauges in the indicating box. This records the air pressure within the cell, which necessarily equals the earth pressure acting on the cell. At the same instant the operator releases the air pressure within the cell, for at no time should he allow the air pressure to exceed the soil pressure by more than 0.1 pound per square inch, since by so doing the accuracy of future readings would be impaired.

It was several years before means could be devised for proving the accuracy of the results obtained where measurements of pressure of granular materials were made, although it was a comparatively easy matter to prove the accuracy of the instrument when used in liquids or semiliquids. The method pursued in checking these results for granular materials consisted in measuring the movement of disk *B* during the breaking of electrical contact. For this purpose a special set-up of the instrument was employed as shown in figure 5. The cell was placed flush with the surface of a reinforced concrete floor and 3 feet of sand was placed over the cell. In place of the wire ordinarily used in the pipe line leading to the cell a brass rod having an ivory tip bearing on the movable disk of the cell was employed. The other end of this rod bore on the plunger of an Ames dial reading movements of 0.0001 of an inch. Concentrated loads were placed on a bearing block resting on the sand fill over the cell and thus definite unit pressures were transmitted to the cell. Air was introduced and simultaneous readings of the air pressure in the cell and movements of the movable diaphragm were recorded at the breaking of electrical contact, and also

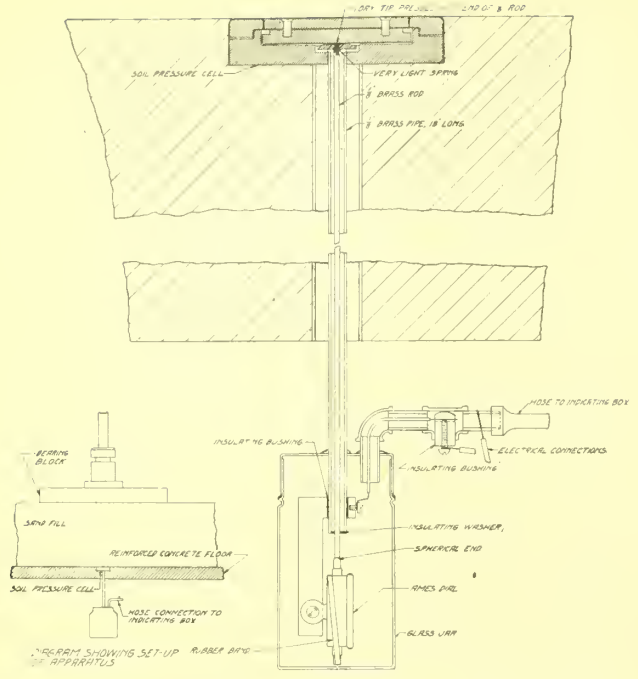


FIG. 5.—APPARATUS FOR MEASURING ERROR IN SOIL PRESSURE CELLS DUE TO SMALL MOVEMENT REQUIRED TO BREAK ELECTRICAL CONTACT.

after contact was broken. The curves in figure 4 show these simultaneous readings. The double circle shows how much movement took place in the instrument up to the point of breaking electrical contact, and the circles to the right of the double circle indicate the movements after the breaking of electrical contact. Before electrical contact is broken the soil pressure is counterbalanced by the internal air pressure plus whatever pressure exists on steel button *E*. After contact is broken within the cell the air pressure alone counterbalances the soil pressure and, therefore, it is known definitely how much increase in internal pressure is required to produce definite movements of the movable disk.

It will be noted that the movement required to break electrical contact for external pressures up to about 15 pounds per square inch is less than 0.0001 of an inch and for low pressures is only 0.00001 of an inch. It will also be noted from the curves that in general less than 0.1 of a pound per square inch increase in pressure is required in order to move the disk against the earth pressure 0.0001 inch or less. The small increase in pressure necessary to produce the exceedingly small movement of the diaphragm required in breaking electrical contact is the error of the instrument, and this is not more than 0.1 of a pound per square inch, since in general less than 0.0001 inch movement is required to break electrical contact.

The results of these tests have convinced us that the instrument gives thoroughly reliable results in granular materials, such as densely compacted sand, as well as in liquids and semiliquids. It has also been demonstrated that it is sufficiently rugged to withstand field conditions, and it might very readily be applied to obtain useful data on many types of construction.

ILLINOIS BUILDS ROADS DESPITE CAR SHORTAGE.

The Division of Highways of the State of Illinois in a bulletin issued recently claims that the work accomplished in the State this year is far in excess of that done by any other State with the exception of Pennsylvania, which is making about the same progress as Illinois.

The division considers its progress under the existing serious economic conditions to be fairly satisfactory, yet it believes that if contractors could get delivery of materials as required, easily twice as much pavement could have been laid during the same period, without any additional expense to the State for supervision and with very little additional overhead expense to the contractors.

It is asserted that the work under way in the State requires approximately 450 cars per day. Assuming that it takes 10 days for a car to make a round between the source of supply and the point of delivery of the material, it would be necessary to place in this service 4,500 cars for the entire season, which gives a startling idea of the magnitude of the difficulties involved under present conditions in obtaining cars for road work.

More than 40 contractors, many of them with two and several with three or more paving machines, have been in readiness since the early part of the season to carry on this work. The conditions have been such that practically none of them have been able to operate more than one machine at a time.

It is not possible to predict how much of the 350 miles of uncompleted contracts can be finished this year; but unless conditions should become worse than they are at present, it is anticipated that the end of the season will find most of the small contractors showing completed sections, while the large contractors will have a very substantial part of their work done. If the entire system can not be completed, there will at least be many stretches of completed pavement 15 to 20 miles in length and several from 70 to 100 miles in length.

Where it is impossible to get materials for surfacing, the division is proceeding with grading work and the construction of small bridges and culverts. In many places there are heavy fills to make, which require at least a year's time for settlement before the pavement can be laid. This work, as well as the bridges in connection with the grading, is well underway. With the heavy grading completed, the State can proceed under better economic conditions, which must come sooner or later, to build continuous pavements, which otherwise would not be possible if it were necessary to delay the pavement work in order to permit grading to settle.

In view of these accomplishments the division feels that the progress made thus far this season is all that could be expected.

SHIFTING SAND STOPPED WITH OIL ON OREGON FEDERAL AID PROJECTS

By A. F. MORRIS, Highway Engineer, U. S. Bureau of Public Roads.

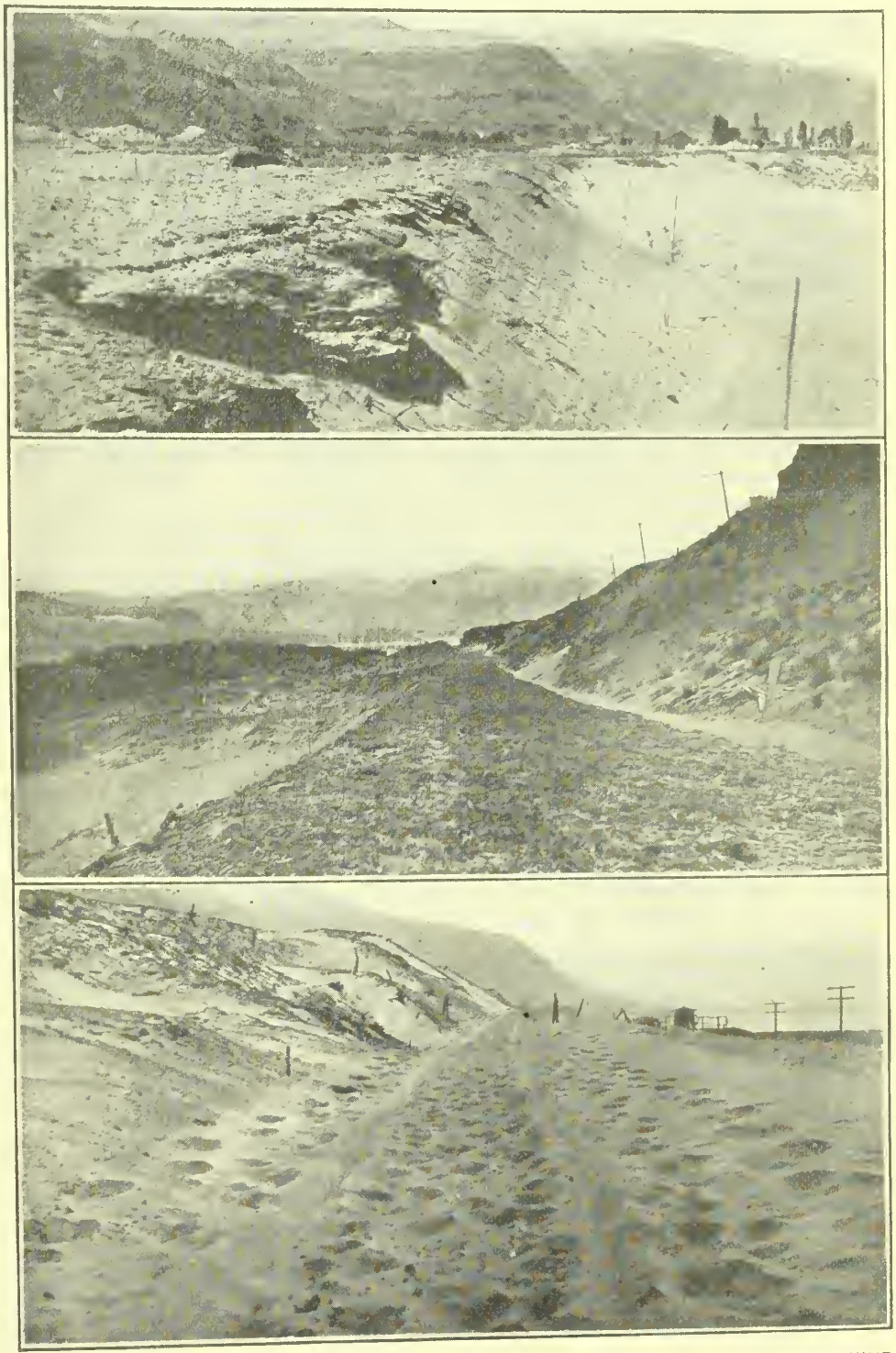
IN THE construction of the Columbia River Highway from Pendleton in eastern Oregon to Astoria at the mouth of the Columbia River, the engineers of the State highway department have encountered more unusual engineering difficulties to the mile than can be found on any other road in the Northwest.

From The Dalles to Astoria the road has now been graded and paved over practically the entire length and has become nationally famous as a scenic highway. Nearly 17 miles of this section of the road extending from The Dalles to Mosier has been constructed with Federal aid.

At The Dalles occurs a very marked change in the nature of the country. Down the river to the west the hillsides are covered with trees, shrubs, and wild flowers and in the ravines crystal-clear streams of sparkling water from the melting snows of the Cascades tumble over the cliffs in beautiful waterfalls.

To the east, along the river is a barren waste of sand and rocky, treeless slopes, while back from the river for miles and miles on both sides extend vast wheat fields. As most of the population of the country is located on this plateau the early roads naturally were constructed there, with short connecting roads from the main east and west highways, through convenient intersecting canyons, to the shipping points on the railroad which followed a water grade along the river.

The location of these early roads was justified by the



USE OF OIL ON ROADS TO CONTROL SHIFTING SAND. TOP—THE EFFECT OF WIND ACTION ON UNPROTECTED FILL SLOPES AT BLALOCK, IN GILLIAM COUNTY, OREG., ON FEDERAL-AID PROJECT NO. 24. CENTER—NEWLY GRADED SECTION OF FEDERAL-AID PROJECT NO. 37, NEAR CELILO, WASCO COUNTY, OREG., COVERED WITH STRAW AND STABLE MANURE. BOTTOM—NEWLY GRADED SECTION OF FEDERAL-AID PROJECT NO. 25, AT SHERMAN, OREG., BEFORE OILING. NOTE THE DEEP RUTS THROUGH THE SAND. IN THE UPPER LEFT OF THE PICTURE IS SHOWN A PORTION OF THE SAND HILL WHICH WAS OILED BY THE RAILROAD COMPANY.

OILING RIG ON FEDERAL-AID PROJECT NO. 25, AT DAY, SHERMAN COUNTY, OREG., IDLE FROM LACK OF OIL.

existing conditions. They best served the local needs, and through traffic, before the day of motor vehicles, had not become a governing factor in highway location; but when the choice of a route for the eastward extension of the Columbia River Highway was made, the matter of grades and alignment had become of major importance. It was, therefore, decided to continue the water grade up the Columbia and overcome the many obstacles to be encountered in such ways as could be devised.

FIGHTING THE SAND DUNES.

For years the railroad company has fought the sand dunes along its line. The Columbia River each year brings down deposits of sand and silt at the time of high water, which occurs in the month of June, when tributaries are swollen by melting snows. When the waters recede and the flow of the stream becomes normal, these sands are left exposed, to be picked up by the winds which blow almost constantly during the summer months, generally upstream, depositing it in sand dunes similar to those found along the ocean beach.

These dunes are constantly shifting and various means have been tried to keep them off the tracks. Low wooden barriers, similar to snow fences, were tried to deflect the sand, and a force of men was employed to clear the track with shovels. These sand fences proved inefficient and other means were tried with but little effect until it was proposed to sprinkle the tracks and near-by dunes with crude oil. This treatment has proved entirely satisfactory, and has completely stopped the movement except where the oiled surface has broken up or new dunes have been formed by sand deposited from distant points. To one unacquainted with them it is difficult to realize the force of the winds which even carry sand from the opposite side of the river, in places a mile away, so that new dunes are constantly being formed, which creep along with the wind until stopped by further applications of oil.

Fifty-three miles of the new highway from The Dalles eastward through this difficult country is comprised in five Federal-aid projects. One short section of 2 miles from The Dalles to Big Eddy is a bituminous concrete road and is entirely completed. The rest of the mileage which is now under construction will be graded only under the present contracts. The total estimated cost of the 53 miles is nearly $1,000,000, half of which will be paid by the Federal Government.

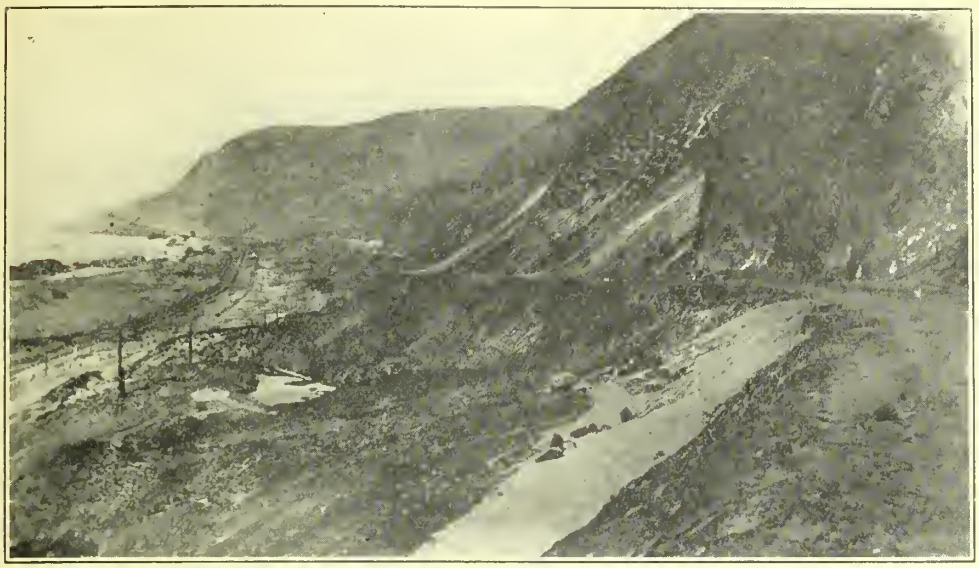
In constructing the new highway it has been necessary to cut through the banks of sand oiled by the railroad company, as well as many new banks which had not been oiled by the railroad forces. In other places, where there are no sand dunes, the soil consists of a volcanic ash as light and fine as flour. As fast as cuts are opened up and fills made in this light soil the wind cuts away the banks and whips out the fill slopes, and sand dunes creep into rock cuts, completely blocking the road.

USE OF OIL IS EFFECTIVE.

To stop the depredations of this mischievous wind some of the early work was covered with straw and stable manure, but while this method was fairly effective in protecting the fill slopes and the roadbed it did not afford the necessary protection to the cut slopes, nor did it stop the smothering inroads of the dunes in the cuts.

Half measures failing it has since been decided to adopt the tactics of the railroad company and oil the slopes and shifting sands as far as possible on each side of the road.

The equipment which is used to spray the crude oil consists of two supply tanks or drums, in which the oil is carried from the storage tank at the railroad siding, and a tractor which draws the oiling rig and supplies the steam through a hose to the compressor tanks, which are carried on a trailer. The oil is heated by the steam and is forced through a hose with a nozzle consisting of a short piece of half-inch pipe. The steam atomizes the oil and sends it in a fine spray for 100 feet or more, depending on whether the spray is projected in the direction of the wind or against it.



OILED SLOPES IN CUT AND FILL ON OREGON FEDERAL-AID PROJECT NO. 25, NEAR RUFUS, SHERMAN COUNTY.

Spraying is generally carried on in the direction of the wind for obvious reasons.

The accompanying photographs show the difficulties encountered and the means of overcoming them. The picture which shows the extent of the distribution of oil over the road side will be particularly interesting to eastern highway officials, who are having no end of trouble in getting the comparatively small quantities of bituminous materials they require for maintenance work. It may be added that the same conditions are seriously affecting the progress of this work. The shortage of cars has kept the supply of oil on hand always reduced to very small quantities, and the work is frequently halted by the total exhaustion of the supply. Indeed, the seriousness of the situation is such as to threaten the use of this most effective treatment entirely, and to force a return to the less adequate measures which have formerly been used, at least until the freight situation improves.

Where sufficient oil is used this means of controlling the sand movement is very effective and it is believed that the cost will not be excessive, though exact figures are not at this time obtainable.

MOTOR TRUCKS ON EASTERN FARMS.

Bulletin No. 919, just issued by the Department of Agriculture, dealing with the above subject, contains a great deal of information which will be interesting to highway engineers.

The bulletin is based on the experience with motor trucks of 753 farmers in the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, and Maryland.

The farmers own trucks of all sizes and types from those of one-half ton to five tons capacity. The rated capacity of very few of the trucks is over 2 tons, however, and nearly half are of 1-ton size.

8801—20——2

Only 18 per cent of the farms are less than 5 miles from market, and nearly one-fourth are 20 miles or more.

In the opinion of the owners of these trucks the principal advantage of a motor truck is in saving time, and the principal disadvantage is "poor roads."

On the average it is reported that there are about eight weeks during the year when the roads are in such conditions on account of mud and snow, etc., that the trucks can not be used. Three-fourths of them usually travel on roads that are all or part dirt.

About one-fourth of the men have changed their markets, for at least a part of their produce, since purchasing trucks. For those who have changed their market, the average distance to the old market was 7 miles, and the average distance to the new market is 20 miles.

According to owners' estimates, each of the trucks travels an average of 3,820 miles per year and is used on 173 days per year.

Most of the owners of one-half and three-fourth ton trucks prefer pneumatic tires, the owners of the 1-ton trucks are about evenly divided in their preference, but most of the owners of trucks larger than 1 ton prefer solid tires.

Over two-thirds of these trucks had not been out of commission when needed for a single day during the year covered by the reports, and nearly the same proportion of the owners stated that they had not lost any appreciable time on account of motor and tire trouble, breakage, etc. However, about 1 truck in 30 had been out of commission 10 days or more.

Return loads are available according to the reports for only about one-fourth of the trips.

The average cost of operating the trucks of various sizes, including driver's wages, as well as the strictly operating charges, was 50.4 cents per ton-mile for the one-half-ton trucks, 33.8 cents per ton-mile for the three-fourth-ton trucks, 25.8 cents for the 1-ton trucks, 24.2 cents for the 1¼ and 1½ ton class, and the 2-ton trucks cost 18.2 cents per ton-mile.

In the above data the drivers' wages included were 50 cents per hour, gasoline and oil cost from about 2 cents per mile for the one-half-ton truck to nearly 4 cents per mile for the 2-ton truck; tires cost 1.6 cents per mile for one-half-ton and 2.5 cents for 2-ton trucks.

Only one per cent of the whole number of replies gave the saving of expense as the principal advantage derived from the use of trucks instead of horses. Two per cent regarded the superior convenience of the truck as its principal advantage; 2 per cent thought that the ability to reach better markets was their crowning advantage; 3 per cent looked upon the saving of horses as the best reason for the use of the trucks; but nearly all, 91 per cent in fact, gave as the principal advantage "the saving of time."

BRITISH ROAD CONDITIONS AND HIGHWAY ADMINISTRATION

LOCAL GOVERNMENT in the British Isles differs so radically from the system of government under which Americans live that it is especially important that one who wishes to understand the methods of highway administration should first acquire a working knowledge of the system of government

The American who interests himself in French highway methods is struck immediately by the close parallelism between the American and French governmental divisions. The national government of both countries is a federal government, a government of federated states or departments which, however, in matters of purely state importance have sharply defined powers of government reserved to them. The departments in turn include subordinate governments of the arrondissement, and the commun, which correspond very closely to the American counties and townships.

No such close parallelism appears when one comes to compare the governments of the British Isles and the United States. The greatest difference, perhaps, lies in the fact that there is no counterpart of the American State, unless the countries of England, Scotland, Ireland, and Wales may be so considered. Territorially, this comparison may serve, but from the standpoint of government there is no likeness whatever. Below the government of the Crown the largest subdivision of the government is the administrative county. These do not coincide territorially with the ancient counties, which, however are still the basis of the system of parliamentary representation. For practical purposes a number of these ancient counties have been combined to form larger administrative counties. Thus though there are in England and Wales 253 county areas, there are only 62 administrative counties. The latter correspond roughly in size and authority to the counties of the United States.

The administrative county is governed by an elected county council, which has jurisdiction over all places within its area with two exceptions; namely, county boroughs and the quarter sessions boroughs.

All boroughs, territorially, are parts of the administrative counties, but in matters of government only one of the three classes of boroughs is entirely subordinate to the administrative county. The three classes are known respectively as county boroughs, quarter sessions boroughs and noncounty boroughs. The distinction is largely one of population, though prior denomination as a county is one of the reasons for the independence of certain county boroughs.

The county boroughs are governed by a borough council, which is independent of the county council, and practically of coequal rank. In this respect they are similar to certain cities of the United States such as New York, Philadelphia, Baltimore, and St. Louis, which either are independent of county control, or occupy an entire county. The quarter-sessions boroughs govern themselves in certain matters, but in the control of highways are subordinate to the county. The third class of boroughs, the smallest ones, known as noncounty boroughs, are in all things subordinate to the administrative county, and are "rated" or taxed for all county purposes.

The boroughs are urban centers. Before 1848 there was, outside of these municipal boroughs, no district government. In that year the whole of England and Wales (subsequently also, Scotland and Ireland) was divided into local government districts. These districts now constitute the prevailing subdivision. They are either urban or rural. Urban districts include boroughs and places which were formerly under the jurisdiction of local boards or improvement commissioners; and it follows therefore that the borough councils of county boroughs have the powers and duties of urban district councils as well as those of county councils. The closest American parallel to these districts whether urban or rural are the New England townships.

The parish, originally a subdivision of the church government, now constitutes also the smallest subdivision of the government of the State. By the act of 1894 it is provided that parishes with a population exceeding 300 must elect a parish council. If it has a population of 100 or upward, the county council is bound to order the election of a parish council if the annual parish meeting so resolves. Where there is no parish council its powers are exercised by the parish meeting itself. Two or more parishes may be grouped under a common parish council by order of the county council, if the parish meetings of each parish consent. An annual parish meeting must be held within seven days before or after March 25; and, if there is no parish council, there must be at least one other parish meeting in the year. No American governmental subdivision compares closely with these parishes; though the parishes of South Carolina have a similar origin, and somewhat similar functions. In urban districts separate parish councils are not elected, but most of the powers of the parish council may be conferred on the district council, and in cases where the parish and urban district are conterminous, all the powers of the

parish council belong to the district council. One body may, therefore, in some cases, exercise the powers of the county council, the district council, and the parish council, but in most rural districts the three coexist with separate powers.

CLASSIFICATION OF ROADS.

All roads in England and Wales outside of London and county boroughs are at present classified roughly as—

1. Main roads, which may be situated in noncounty boroughs, urban districts, or rural districts, and
2. Roads other than main roads (generally called "District roads") in noncounty boroughs, urban districts, and rural districts.

In county boroughs and in London roads are not subdivided as between "main" and "district" roads.

In Scotland the classification is—

1. Roads in urban areas, cities, and burghs.
2. Rural roads.

The designation "main roads" does not necessarily mean that such roads are "important roads," but merely that the cost of maintenance is paid for out of county "rates" or taxes which are levied not only on rural districts, but also on the noncounty boroughs and urban districts in the county. Most main roads are those which were formerly turnpikes, but any road can be declared to be a main road by the county council on the application of a district council. In similar manner any main road may be "dismained," in which case it reverts to the status of a district road.

In reality it will be seen that there is at present in the British Isles no classification of roads upon the basis of importance. The classification as between "main" and "district" roads is merely a division upon the basis of control.

However, the newly created roads department of the ministry of transport is now engaged in acquiring from the various governmental subdivision the necessary data as to the character of the roads within their respective limits upon which a true "importance classification" will be based. According to the circular of the ministry of transport "the classification is to be made on the basis of the relative importance of the various highways for general traffic purposes, and regard will be had to the consideration whether a road proposed to be classified is an important arterial route for through traffic or possesses more than local importance." The roads will be divided into three classes designated, first class, second class, and third class. No precise definition can yet be laid down as to the roads which will be included in the respective classes, but it is stated that streets in county boroughs will not be considered for classification as first or second class. After the basic data has been acquired from the counties and districts, traffic censuses will be taken at points designated by the ministry, and upon the basis of this data and the recommendation of local officials the final classification will be determined by the ministry.

ADMINISTRATION OF HIGHWAYS.

Prior to 1909 there was no national agency empowered to exercise control over the highways of the British Isles. In that year the road board, a national agency, was constituted and empowered to assist the local authorities in the construction of roads with grants from the national treasury. The particular projects to be assisted were left to the discretion of the road board, as was also the amount of the Government contribution, except that the act creating the board expressly prohibited the granting of national funds for maintenance.

In its first report the board defined the character of works which might receive its assistance as follows:

1. Reconstruction of important roads, the condition of which is exceptionally bad and can not be improved without reconstruction.
2. Widening of important roads which are dangerously narrow.
3. Surfacing with granite, basalt, or other suitable material treated with tar or other bituminous compound by some approved method, main roads or important district roads which already have adequate foundations, especially those on or just beyond the outer fringe of large towns which have to carry a heavy traffic without aid from rates of the towns served by the roads.
4. Opening out of dangerous corners and alterations of dangerous curves.
5. Alteration, where possible at reasonable cost, of steep and dangerous gradients.
6. Strengthening or reconditioning of weak bridges, which seriously limit the use of commercial transport or roads of first-class importance.
7. Construction of new by-pass roads to avoid villages on main roads or important district roads where the conditions are exceptionally dangerous.
8. Acquisition in urgent cases where building is imminent of vacant land required for future widening of roads, especially in urban or suburban areas.

PROCEDURE TO OBTAIN NATIONAL AID.

Local authorities desiring grants of national funds for road work in contemplation were required to submit to the road board a general statement indicating the works for which assistance was desired. The statement was not usually treated as a formal application, but was followed by an interview between the board and representatives of the county council, at which more or less definite arrangements as to the

amount of the grant were decided upon. The county council were then required to submit detailed plans, specifications, and estimates, upon the receipt of which the road board submitted the case to the treasury for sanction, and made formal announcement of the grant. The construction when it was finally begun was subject to the approval of the road board.

In addition to this work in connection with the supervision of nationally aided construction, the road board, during the 10 years of its existence as a separate body, also undertook other helpful works, such as the standardization of the sizes of broken stone, and the operation of a testing laboratory for bituminous and nonbituminous construction materials.

In 1919 all the powers of the road board were transferred to the newly created ministry of transport, which was also empowered and directed to authorize the expenditure of national funds for maintenance purposes. The procedure to be followed in the granting of national funds is apparently unchanged.

LOCAL ROAD ADMINISTRATION.

England and Wales.—While the national authority, which is now the ministry of transport, exercises supervision over the construction and maintenance of roads upon which national funds are expended the actual work of construction or maintenance is performed under the direction of the county councils; and, indeed, the immediate control of all road work in the British Isles is vested in local authorities.

The "main" roads, previously defined, are paid for out of county taxes, and in general are constructed and maintained by the county councils, but it does not always follow that the actual work is performed by county officials. Some main roads in urban areas, usually called "claimed urbans" are main roads which the urban district authority has claimed under statutory power to maintain by its own staff, charging the cost against the county council. These are roads which existed, as main roads (of which half the cost was then paid out of county taxes), in urban areas, before the passage of the local government act of 1888.

Other main roads in urban areas and also some main roads in rural districts are maintained by the district councils by arrangement with the county councils. There is no uniform policy or system throughout the country, the local authorities concerned having been allowed to settle the matter according to their local circumstances and views.

Broadly speaking, however, most main roads, except:

1. Main roads in claimed urbans,

2. Main roads in some counties, such as Yorkshire (West Riding), in which the work of maintaining the main roads is generally left to district councils subject to some general supervision by the county surveyor, and

3. Some main roads in large urban areas are maintained not only at the cost of the counties but also directly by the county surveyor and the staff of the county council.

District roads are maintained by the council of the borough, urban district, or rural district in which they are situated, payment therefor being generally made out of taxes locally levied, with assistance in some few cases of payments by county councils out of county rates.

Highways in county boroughs are maintained by the municipal authority out of local taxes; and roads and streets in the city of London are maintained by the Corporation of London. In the administrative county of London the work is under the supervision of 28 metropolitan borough councils, each of which has a borough surveyor and staff. The cost of maintenance in each borough is paid for out of rates levied exclusively upon the borough concerned.

Scotland.—In Scotland the sytem of road administration as regards rural roads is more uniform than in England and Wales.

Roads in urban areas, cities, and burghs are maintained by the municipal authorities of these areas exclusively out of local rates.

Rural roads are maintained in one or two counties by the county council, but in most counties by district committees of the county council. These district committees, although their aggregate expenditure is subject to the general financial control of the county council through a statutory committee known as the county road board, are entirely independent of each other and free from any interference or control from the county council in the practical conduct of their work. Each committee has a surveyor who looks after the roads in its district, and the cost of maintainance is raised by rates levied exclusively upon the taxpayers of the district.

For all practical purposes, therefore, districts are treated as though they were counties, and in Scotland, where many counties are very large and sparsely peopled, there is a good deal to be said for the division of the county into districts. The Scottish system has this advantage over the English system—that all roads in a district are under one authority, who can regulate their expenditure on each road according to its importance, and adjust their annual expenditure more easily. It has all the disadvantages which everywhere accompany the subdivision of road authority into small units.

Ireland.—The system of road maintenance in Ireland differs from that in operation in England and Scotland. Outside urban districts, the roads are maintained by the county surveyor, who is employed by the county council. Rural districts do not have a separate highway surveyor or highway staff, but they have joint control with the county council over

expenditures. All expenditures on roads in a given rural district, however important the road may be, must be proposed in the first case, by the rural district council, and then confirmed by the county council. If the rural council is not willing to propose the expenditure the county council can not authorize its surveyor to spend the money. This system of dual control is a great obstacle in the way of the improvement and proper maintenance of roads in Ireland.

SOURCES OF FUNDS.

Revenues to be expended solely by local authorities for the maintenance and repair of highways are derived from the following sources:

1. General or special district taxes levied upon the same basis as the poor-law rate, but with the difference that agricultural land, railways, canals, tithes, and tithe-rent charges are assessed at only one-quarter of their poor-rate valuation.
2. National contributions under the agricultural rates acts.
3. Subventions from the exchequer contribution account of one-half the salaries of the local government board.
4. The proceeds of any district property.

Funds of the third class named constitute the balance which remains in the Government grants to each county after the services to which it is applied are paid for. In 1888 when it was first established in its present form, this balance was understood to represent one-half of the cost of maintenance of main roads, but owing to gradual increases in the prior charges on the fund, the amount of the balance has decreased in all counties, and in at least one has entirely disappeared. The amount of the balance which remains varies, therefore, in different counties, amounting in a few cases to more than the total main-road expenditure, while in the majority of cases it is insufficient to pay 50 per cent of the cost of the main roads, and in one case no balance is available after the prior charges have been met. After these charges the total balance of this grant generally amounts to a sum slightly exceeding 1,250,000 pounds sterling, or in American currency, at the rate of $4 to the pound sterling, $5,000,000.

County and burgh authorities in Scotland receive each year from the local taxation account, £35,000, or $140,000.

National contributions under the agricultural rates acts are not made specifically for roads, but each year some counties allocate sums out of these grants to the roads and bridges account. Sums so allotted are not defined and vary locally.

The general or special taxes levied upon land and property are levied impartially upon all land in the county or district, and bear with no greater severity upon abutting land than upon other land in the county or district.

SOURCES OF NATIONAL ROAD FUNDS.

The foregoing are the sources of funds for road purposes administered solely by local authorities. The funds dispensed by the road board in national grants to encourage construction were provided for by the development and road improvement funds act of 1909, and consisted of the revenues derived from a tax on motor fuel, and any surplus of license fees on carriages (including motor cars) beyond the yield of those fees in 1908. These were transferred annually from the exchequer to the road improvement fund, and, together with accretions due to interest and profit on investments, were devoted to the works aided by the road board. The receipts credited to the road improvement fund from the date of the passing of the act up to August, 1915, when, on account of the war, payments from the exchequer were suspended, amounted to £7,240,000 or (at $4 per pound sterling) $28,960,000. The interest payments continuing, the fund had grown by 1919 to £7,761,005.

During the war various Government departments made contributions to local authorities in Great Britain and Ireland on account of extraordinary damage to public roads by public traffic, the amount of which up to October 31, 1918, was £2,730,912, or approximately $10,924,000.

After the war, in 1919, a grant of £8,000,000 ($32,000,000) was voted by Parliament for the purpose of restoring roads in Great Britain damaged by extraordinary traffic during the war, and a sum of $1,200,000 was voted for a similar purpose in Ireland. These grants, however, were not specifically devoted to works of improvement.

NEW SOURCE OF FUNDS PROPOSED.

The motor fuel and carriage revenue payments from the exchequer having been suspended by war-time act, the road board, or as it now is, the roads department of the ministry of transport is left practically without continuing funds. Accordingly, in 1919, the matter of devising a scheme for the raising of national highway funds was referred to the departmental committee on the taxation and regulation of road vehicles. The problem is to raise an annual net revenue of approximately £7,000,000, which, after payment of the contemplated contributions by the Central Government toward the maintenance of first and second class roads will provide a sufficient sum to enable a substantial measure of new road construction and road improvement to be undertaken forthwith.

The report of the committee, published this year, favors the abolition of the motor fuel tax and substitution of a single revised tax on all motor vehicles, to be levied in accordance with the following scale:

RECOMMENDED SCALE OF MOTOR FEES.

Class of vehicle.	Suggested rate.			
	£.	s.	d.	Dollars.[1]
Motor cycles (up to and including 200 pounds weight)	1	10	0	6.00
Motor cycles (over 200 pounds weight)	3	0	0	12.00
Motor cycles (with trailer or side car)	4	0	0	16.00
Other motor 3-wheelers (except electrical or mechanical or other vehicles for invalids not exceeding 5cwt. in weight)	4	0	0	16.00
Motor bath chairs and other motor vehicles for invalids, not exceeding 5 hundredweight		5	0	1.00
Private motor cars [2] (including 3-wheelers) weighing—				
7 hundredweight or over, unladen, per horsepower	1	0	0	4.00
With minimum of	6	0	0	24.00
Tram cars		15	0	3.00
Hackney vehicles:				
In metropolitan area and such other districts as ministry of transport may define—				
Seating capacity 1–5	15	0	0	60.00
Seating capacity 6–14	30	0	0	120.00
Seating capacity 15–20	45	0	0	180.00
Seating capacity 21–26	60	0	0	240.00
Seating capacity 27–32	72	0	0	288.00
Seating capacity over 32	84	0	0	336.00
In other districts—				
Seating capacity 1–5	12	0	0	48.00
Seating capacity 6–14	24	0	0	96.00
Seating capacity 15–20	36	0	0	144.00
Seating capacity 21–26	48	0	0	192.00
Seating capacity 27–32	60	0	0	240.00
Seating capacity over 32	70	0	0	280.00
Commercial goods vehicles (motor trucks) (including 3-wheelers weighing 7 cwt. or over unladen):				
Not exceeding 12 hundredweight unladen weight	10	0	0	40.00
Over 12 hundredweight but not over 1 ton unladen	16	0	0	64.00
Over 1 ton but not over 2 tons unladen	21	0	0	84.00
Over 2 tons but not over 3 tons unladen	25	0	0	100.00
Over 3 tons but not over 4 tons unladen	28	0	0	112.00
Over 4 tons unladen weight	30	0	0	120.00
Any of the foregoing with right to draw trailer	[3] 2	0	0	[3] 8.00
Other commercial and agricultural vehicles, motor tractors [4]	21	0	0	84.00
Road locomotives and agricultural engines: [4]				
Not over 8 tons unladen	25	0	0	100.00
Over 8 tons but not over 12 tons unladen	28	0	0	112.00
Over 12 tons unladen	30	0	0	120.00
Agricultural tractors used solely for agricultural hauling:				
Over 2½ tons but not over 5 tons unladen	6	0	0	24.00
Over 5 tons unladen	10	0	0	40.00

[1] Rate of exchange 1 pound sterling = $4.
[2] Electrically-propelled private cars to pay only the minimum of 6 pounds. Owners of private motor cars (not including motorcycles) who can show that the engine of their car was constructed prior to Jan. 1, 1913, to be entitled to rebate of 25 per cent of the tax.
[3] Additional.
[4] Including legally permitted trailers.

The committee has recommended that fees collected in accordance with the above schedule, as well as drivers' licenses and penalties for violation of the motor vehicle laws, less the costs of collection, be devoted to purposes of road construction and maintenance.

The objection to the tax on petrol has been that it did not cover the other liquid fuels, such as benzol, kerosene, paraffin, power alcohol, etc. A further point was that if it had been decided to go on with a fuel tax it would have been necessary to raise the rate from 6d. (10 cents) per gallon for pleasure vehicles to 1s. 3d. (25 cents), and the commercial tax from 3d. (5 cents) to 7d. (12 cents), or if a flat rate were preferred to 1s. (20 cents) all around.

Though the petrol tax will be abandoned, if the committee's recommendation is carried out, and though it is also recommended that the new tax be the sole tax collectable, replacing all local vehicle taxes, there is nevertheless a pronounced feeling, especially among motorists, that the rates proposed are excessive, and there is likely to be a good deal of opposition to it. Compared with prevailing American license fees, the tax proposed for automobiles does seem excessive, but the rates for motor trucks appear rather moderate.

NATURE OF LOCAL ADMINISTRATIVE CONTROL.

As the county councils administer the main roads of the country it may suffice to describe the nature of the administrative control exercised by these bodies as typical of the character of local highway administration in general.

A county council is composed of ordinary members elected for three years and aldermen chosen for six years by the whole council. The number of councillors was originally left to be fixed by the local government board, as were the electoral divisions, which were intended to be as nearly as possible equal in population; and both the number of members and the electoral divisions may be varied from time to time by the board on representation of the council.

The aldermen are one-third of the number of councillors, and apart from their longer term of office they have no special privileges. The council elects a chairman and vice chairman who hold office for one year, but are usually reelected. The ordinary council meets only some four times a year, and so conducts its business chiefly by committees. These have charge of the administrative work and direct the permanent officials. The business of the council is to determine questions of policy and control the actions of committees. But inasmuch as the council meets ordinarialy only once a quarter, it is customary to delegate to the committees full powers to act in particular matters in order to expedite business. However, the power to levy taxes or raise loans can not be so delegated.

Under the administrative control of the committees the county business is handled by a group of permanent officials, among whom are the highway officials, known as "surveyors," headed by the county surveyor, who receives about $2,500 per year. He is assisted by a deputy engineer, at about $2,000 per year, an engineering assistant at $1,500, and three or more district surveyors, who receive about $1,500 per year. These men are responsible for the engineering features of construction and maintenance.

The contract system for building and maintenance is almost entirely done away with, the work being carried out by county forces.

Convict labor is not employed on road work, and the only measure resembling the system of convict labor as it obtains in the United States is the use of so-called "casuals" or tramps who stay over night at workhouses, and are required in the morning before leaving, to break a certain quantity of stone for road purposes. This stone is sold by the workhouse authorities, and yields somewhat more than the expenditure upon the "casuals."

MILEAGE OF ROAD AND ROAD EXPENDITURES.

According to the most recent reports, those for 1913–14, there are 152,085 miles of road of all classes in England and Wales; 24,908 miles in Scotland, and 59,150 miles in Ireland.

In England and Wales, and Scotland, the reported mileage is divided into classes according to administration as follows:

ENGLAND AND WALES.

Class of road:	Mileage.
Main roads—	
Urban districts and noncounty boroughs	4,366
Rural districts	23,833
Other roads—	
Urban districts	11,871
Noncounty boroughs	4,867
Rural districts	94,628
Roads in county boroughs	10,304
Roads in corporation of London	48
Roads in metropolitan boroughs	2,168
Total in England and Wales	152,085

SCOTLAND.

	Mileage.
Roads under county councils	22,664
Roads in burghs	2,244
Total in Scotland	24,908

No classification of the mileage of roads in Ireland is available.

Expenditures for maintenance and improvements upon the whole mileage of roads in the Islands, from 1909 to 1918, as far as these data are available, are tabulated in the following table. It should be noted that all works of maintenance are conducted by the local authorities, who also carry on certain work, such as resurfacing, widening, etc., which are classed as improvements, and may be regarded as construction. In addition to the works of improvement conducted by the local authorities with local funds, there are the works carried on with the assistance of road board grants, the character of which has already been described.

STATEMENT OF ROAD MILEAGE AND REVENUES, BY YEARS.

Year.	Mileage.			Expenditures for improvements.						Expenditures for maintenance by local authorities.		
				[5] By Imperial Government.			By local authorities.					
	England and Wales.	Scotland.	Ireland.	England and Wales.	Scotland.	Ireland.	England and Wales.	Scotland.	Ireland.	England and Wales.	Scotland.	Ireland.
1	2	3	4	5	6	7	8	9	10	11	12	13
1910	150,918	24,831	58,334				£416,489	See col. 12	See col. 13	[1] £14,162,641	[2] £1,193,653	[2] £1,068,366
1911	150,671	24,816	58,334	£8,420			585,041	do	do	[1] 14,612,962	[2] 1,242,755	[4] 1,080,794
1912	151,472	24,816	58,334	186,059	£40,931	£18,848	552,936	do	do	[1] 14,724,439	[2] 1,305,003	[4] 1,144,711
1913	151,920	24,859	58,334	308,031	45,987	24,265	486,565	do	do	[1] 15,382,185	[2] 1,347,491	[4] 1,163,878
1914	152,085	24,908	58,334	544,608	64,742	30,363	562,598	do	do	[1] 16,139,571	[2] 1,413,383	[4] 1,178,649
1915	[3]	24,908	59,150	731,954	91,937	62,844	See col. 11	do	do	[2] 16,283,300	[2] 1,484,147	[4] 1,209,206
1916	[3]	[3]	[3]	404,759	50,748	43,650	do	do	do	[2] 15,566,170	[2] 1,368,222	[4] 1,199,712
1917	[3]	[3]	[3]	256,771	33,107	28,758			do	[3]	[3]	[4] 1,181,907
1918				166,302	22,845	20,307				[3]	[3]	[3]
1919				166,600	20,911	31,851				[3]	[3]	[3]

[1] Includes expenditures for cleaning and loan charges, but not for improvements.
[2] Includes expenditures for improvements and loan charges.
[3] Not reported.
[4] Includes expenditures for improvements and cleaning, but not loan charges.
[5] Includes Road Board grants paid only.

NOTE.—Up to Oct. 31, 1918, a total expenditure of £2,730,913 had been authorized by Government departments other than the Road Board, largely to repair damage to roads due to war traffic.

CHARACTER OF ROAD CONSTRUCTION AND MAINTENANCE.

British roads outside of incorporated cities and towns are generally surfaced with water-bound or bituminous macadam. Surface treated water-bound macadam is also in very general use for ordinary rural roads. For heavy traffic arteries the practice in the past has been to resort to granite blocks or "setts," or wood blocks on concrete foundations. The granite "setts" are no longer desired, on account of the roughness of the surface, and wood blocks are reported as very expensive and difficult to obtain. Water-bound macadam has proved unsatisfactory under motor traffic; and as a result British road authorities are conducting a number of experiments, dealing largely with various types of bituminous roads, in the hope of finding a suitable surfacing material. Portland cement concrete has not so far taken anything like the prominent place it does in this country. However, the subject of concrete roads was one of those most thoroughly discussed at the recent Roads and Transport Congress held in London in November, 1919, and apparently the concensus of opinion was in its favor, certainly for towns, "provided a surfacing material (of tar and granite chips) is used to render the roads suitable for horse traffic."

An interesting reflection of the present state of opinion in regard to concrete is contained in a recent clipping received from the Newcastle Evening Chronicle, as follows:

"Northumberland County Council has the distinction of being one of the first public bodies in England to adopt the ferro-concrete system of road making, a start having already been made on a stretch three quarters of a mile in length at Wideopen. The success of this initial step will be watched with much interest, because on it depends the extent to which this form of road making will ultimately be applied to the whole country. For the concrete road it is claimed that it is more durable, and more economical in the long run than others, and provides an excellent surface for all sorts of traffic. Of course in frosty weather a concrete road, like any other, would have to be 'gritted'."

Assuming the practice in the counties of Devon and Cornwall to be typical of the general practice through-

out the Islands, the average rural macadam roads are built 18 inches thick, including a Telford base. Main roads are built not less than 18 feet wide, and no grade crossings are permitted. Culverts and bridges are of stone or steel, the smaller ones frequently of vitrified clay.

Data on the costs of construction and maintenance are reported by a number of consuls, and are in fair agreement. For ordinary rural roads it is reported that 4½ inches of tar-macadam surface costs at present as high as $3.40 per square yard. Seven inches of water-bound macadam costs $2.15 per square yard. A 10-inch foundation of larger rocks costs $1.10 per square yard. A 4-inch concrete base costs approximately $1.50 per square yard. For very heavy traffic a surface of stone "setts" laid on a 9-inch concrete base will cost nearly $12 per square yard. A surface of Baltic red wood block on a 6-inch concrete base, costs at present prices over $13 per square yard. The prices quoted are furnished by the city engineer of Liverpool.

Maintenance figures quoted from the same authority vary from 30 cents per square yard for a granite-set pavement under heavy traffic to 9 cents per square yard for the same pavement under average city traffic. It is stated that the red wood surface will require an expenditure of 30 cents per square yard per year to keep it in condition; a pitch-macadam surface 14 cents and a water-bound macadam surface as high as 56 cents per square yard per year. It should be noted, however, that these prices probably apply to city conditions, and the city engineer states that they include cleaning as well as maintenance of the surface.

ROAD CONDITIONS AND TRAFFIC.

As elsewhere throughout the world wherever the effects of the war were felt the roads of the United Kingdom have seriously deteriorated since 1914, due to the cessation of proper maintenance and repair and the extraordinary development of highway transportation. To provide for the repair of roads damaged by war traffic several Government departments have extended grants of money to the various local authorities, but these have not approached in amount the large expenditure which will be required to restore the roads and fit them for the augmented traffic of the present day.

The conditions of rail transport are even more chaotic perhaps than in the United States. There is a shortage of freight cars and a depreciation generally of all rolling stock and road beds, to repair which it has already been necessary to effect one advance in rates, which is likely to be followed in the near future by another. As in the United States serious congestion of the railways and delays in transit have caused an enormous development in motor transport of merchandise, and road organizations similar to the "return loads bureaus" which sprung up here during the war are fostering the new highway traffic and bringing the truck owner into contact with prospective clients. The change in the system of taxation from a tax on fuel to what appears to be an exceptionally favorable tax per vehicle for motor trucks will undoubtedly further advance the use of the motor trucks.

As an example of the character of service furnished by the truck transport companies and the cost of such service the following extracts from the report of the American consul general at London may be of interest. The information is supplied by Messrs. Carter, Peterson & Co., one of the chief haulage contractors in or around London. "The figures given are based on cost and do not include the expenses of the selling department of a transportation business. The concern furnishing these figures is one for the distribution of various packages, the average weight being approximately 40 pounds. Transit is effected by road to local delivery offices situated in the various boroughs surrounding the City of London, and delivery effected thence to retail shops or direct to private houses. The zones covered by the Carter-Peterson service are, firstly, the area of London proper, and the residential suburbs surrounding it. The three zones surrounding it approximate to 30, 50, and 70 miles radius from the center of London. All point-to-point transfer services within the area are carried out by motor lorries, running to time-tables like passenger trains. The aim of this company is that one of its local collection vans should pass down each street in the area, at least once every day—consequently, the public are able, by exhibiting a card in the window, to attract the notice of the carman, who thus collects any traffic there may be for him." The cost information supplied is based on the costs of a 4-ton Leyland truck, adding a profit of 7 per cent. It is assumed that there will be constant work for the vehicle, providing full loads outward and inward, without overtime; the working day being 8 hours and the average speed of the vehicle 10 miles per hour. The rate of exchange from English currency has been taken as $4 to the pound sterling.

Cost per ton-mile, $0.083.
Load carried, 4 tons.
Nature of freight, general goods.
Kind of vehicle, 4-ton-gasoline-driven.
Depreciation, 15 per cent on capital outlay.
Maximum load, 4 tons.
Drivers' wages, $15.80 per week.
Total mileage, 60 miles per day.

In view of the impression that prevails in this country that the truck, as an agent of transportation, has an advantage over the railroads by virtue of its independence of labor troubles, it is interesting to note that in England a strike of motor-truck operatives last spring tied up practically all transportation by highway, and was settled only by granting an advance in wages amounting to about $1 per week.

Profiteer-ridden Americans may also find the consolation which is derived from company in misery, in the report of an alleged combine to control road-transport rates in England. An investigation conducted last February, however, by the central profiteering committee resulted in a Scotch verdict "not proven." The report of the committee points out that the importance of road transport as a factor in raising the cost of living lies in that it enters into the cost of production of every article of use or consumption. Indeed many commodities are carried by road five or six times before coming to the consumer. According to the report the cost of transportation in England has risen 300 per cent since 1914.

DENSITY OF TRAFFIC.

Some idea of the density of highway traffic and, consequently, of the highway problem which exists at the present time may be gleaned from the figures presented by the committee on taxation of road vehicles. According to the committee the numbers of vehicles of various classes in England and Wales at midsummer 1920 will be as estimated in the following table:

MOTOR VEHICLES IN ENGLAND AND WALES.

Class.	Number (summer of 1920).
Cycles	265,000
Private cars	210,000
Hackney vehicles	70,000
Commercial goods vehicles	100,000
Other commercial and agricultural vehicles	7,500
Total motor vehicles	652,500

The magazine "Modern Transport" publishes an estimate which agrees with the above only in the number of private cars. Its estimate of the total number of vehicles of all classes is only 311,000.

If the committee's estimate is correct there are in England and Wales 2.5 motor vehicles, excluding cycles, for each mile of road, as compared with the average density of 3.05 in the United States. If Modern Transport is nearer to the facts, then there are only 2 motor vehicles for each mile of road, including cycles. Figures supplied by the American Exporter which rate the number of motor vehicles in Great Britain at 255,000 are lower than either of the British estimates but conform more closely to the estimate published by Modern Transport.

WISCONSIN'S MAINTENANCE POLICY.

In planning the maintenance of the State trunk highway system the Wisconsin commission decided at the outset to install a thorough system of patrol maintenance, supplemented in practically all counties by small gangs for reconstruction and heavy repair work.

The commission did not advocate the promiscuous regrading of all roads on the system immediately. Those that could be maintained reasonably well by ordinary patrol maintenance methods were permitted to wait a year or more until the necessary funds were made available for this purpose.

Sections of the system that lacked drainage, cuts and fills that were dangerously narrow, dangerous turns, and surfaced roads that required additional shoulders and resurfacing received attention as early as possible in order to get the best results under the patrol system.

The additional 2,500 miles authorized by the legislature of 1919 has been selected by the legislative committee and the highway commission and will be handled in all ways the same as the original 5,000 miles were handled.

In certain sections of the State, especially in undeveloped portions of northern Wisconsin, there are portions of certain new trunk highways that will not be maintained for one or more seasons. The portion not to be maintained for 1920 amounts to about 300 miles, and in practically all cases there is no road that is fit to travel at the present time. As soon as a road has been laid out and is in reasonably fit condition for a patrolman to maintain, it will be taken over for maintenance,

The following specific policies have been put into effect:

1. The system lying in each county is divided into patrol sections, averaging from 6 to 8 miles in length.
2. A patrolman is engaged for each section, who devotes all his time to the work for the entire maintenance season, which is about seven months in northern counties and eight months in southern counties.
3. Patrolmen are paid a monthly salary sufficient to attract good men. The patrolman must furnish a satisfactory team and wagon, the county furnishing a light blade grader, road planer, plow, slip scraper, and other necessary tools.
4. The patrolman is responsible for the maintenance of his section, and where extra help is necessary to adequately maintain any particular section, it is furnished by the county, but the work is done under the direct supervision of the patrolman. The basic idea is to place responsibility "on one man only, the patrolman."
5. The patrolman reports daily and monthly to the county highway commissioner, showing the hours worked and their distribution. The monthly reports are forwarded to the division engineer's office by the county highway commissioner, and show the cost and distribution of both labor and material used on each section. These reports must be received by the county highway commissioner before the patrolman's salary will be paid.
6. Small gangs are organized in each county, equipped for the special work required, according to the type of road to be maintained; a gang for applying surface treatments; one for heavy blade grader work; one for scarifying and shaping up old gravel and macadam roads; one for resurfacing.

VALUABLE STUDY OF MOVEMENT OF CAPILLARY WATER IN SOIL

BULLETIN NO. 835, entitled "Capillary Movement of Soil Moisture," by Walter W. McLaughlin, senior irrigation engineer of the Bureau of Public Roads, has just been issued by the Department of Agriculture.

While it is written primarily from the standpoint of the irrigation engineer, the tests which it describes and the observations it records are of great interest to highway engineers as well.

Capillary attraction has for some time been recognized as a probable cause of the high moisture content of soils composing road subgrades under certain conditions, but unfortunately scientific knowledge of the movement of capillary water is exceedingly meager—so meager, in fact, as to provide no adequate basis for the development of measures of combating the conditions to which it gives rise.

The Division of Tests of the Bureau of Public Roads is at present engaged upon a series of tests to discover the sources of water found in actual subgrades, and to determine the effect of such water upon the bearing power of the soils. The methods adopted in making these tests were described in Public Roads, Vol. 2, No. 24, but, as yet, they have yielded no important results.

It is certain, however, that the careful observations recorded in this new bulletin by an engineer of the irrigation division of the Bureau of Public Roads will throw a great deal of light on many of the conditions observed in the collateral highway tests.

The tests described include observations of the movement of moisture under the two commonly existing conditions:

1. Where the source of the moisture is a body of free water.
2. Where the source of moisture is a body of moist soil, not connected with a body of free water.

MAKING THE TESTS.

The soils tested were packed in flumes; some open so as to allow evaporation to take place, others closed to prevent evaporation. One side of the flumes was of glass so as to permit the movement of the moisture to be observed.

The flumes were set horizontally, vertically, and at various angles with the horizontal, and in each position were packed with a number of representative soils varying from light sandy varieties to heavy clay. This arrangement provided for the study of the rate and extent of the capillary movement in columns of various types of soil under conditions designed respectively to eliminate the attraction of gravity as a factor, to include it as a counter attraction to the capillary force, and to include it as an assisting force.

In connection with the experiments, records were kept of the air temperature and the evaporation from a free-water surface.

The results of the tests of vertical soil columns confirm in the main the observations of other investigators of the vertical movement of capillary water. The observations indicate that the rate of movement in the lighter soils is more rapid for the first few hours and then slows down much quicker than in the heavy soils. In general, it was found that the lighter the soil the shorter would be the distance the moisture would move upward in a long period of time.

The horizontal capillary movement of moisture has not been studied to any great extent before. In respect to the rate of movement in the lighter and heavier soils the phenomena noted in the case of upward movement are exactly reversed when the movement is horizontal. The extent of the movement in the various soils, with one exception, was in inverse order to their moisture equivalents. The light soil with the lowest moisture equivalent showed the greatest movement of moisture while the heavy soil with the greatest moisture equivalent showed the least movement of moisture. The lighter soils used the greater total quantity of water in long periods of time and moved it farther in the horizontal direction than the heavier soils. These are the opposite of the conditions noted in connection with the vertical movement, and should be of particular interest to highway engineers, in view of the fact that the horizontal movement of water from road shoulders toward the center of the pavement must be fully as great as the upward movement of water from underground sources.

The phenomena noted in connection with the movement in flumes tilted at various angles to the horizontal combine the characteristics of the movement in the two cardinal directions as might be expected.

VALUE TO HIGHWAY ENGINEERS.

Among the observations of greatest significance to highway engineers are those which refer to the effect of temperature upon the movement of capillary water. The experiments indicate that a temperature of from 26° to 32° F. has a marked influence upon soil moisture other than the mere fact of freezing. A number of the horizontal flumes tested when the temperature was or recently had been below 30°, consistently showed greater percentages of moisture near the top of the flumes than near the bottom. Basicly the percentage of moisture in the top samples should be less than that

in samples from the bottom layers. In the first place gravity tends to draw the moisture to the lower layers. Secondly, evaporation tends further to reduce the moisture at and near the surface. Thus the laws of physics would indicate a lower percentage of moisture toward the top of the flume than near the bottom. There were, however, several instances where this relationship was interchanged, and more especially was this noticeable during the winter of 1916–17. When this interchanged relationship was observed so frequently during the spring of 1917 as to almost preclude the probability of error in sampling, it seemed evident that the unlooked-for distribution of moisture was the result of some natural condition. It soon became apparent that the top part of the flumes showed the greater percentage of moisture during only that part of the year when the air temperature was or recently had been below 30°. Looking back over the results of the preceding winter, the same condition was found. When these facts became evident it was so late in the season that there was no opportunity to prove the matter beyond a question of doubt. Before a definite conclusion can be drawn, therefore, additional experiments will have to be made. The covered flumes seemed to require a somewhat lower temperature to produce the condition than the open flumes. These observations are so suggestive as a possible explanation of the saturated condition of road subgrades in the spring of the year as to merit the fullest investigation by highway engineers.

The bulletin is now available for free distribution and all who are interested may obtain a copy by applying to the Chief of the Bureau of Public Roads.

MAINTENANCE ON ENGLISH ROADS.

During the year ending in March, 1920, maintenance upon the Essex, England, county main roads, aggregating 672 miles, cost the county authorities, according to the annual report of the county surveyor and recently reported in the "Surveyor," a total of £162,065, or an average of $1,170 per mile. Essex County main roads total 788½ miles, though 116½ miles are under urban authority, making the length under the direct control of the county council 672 miles.

Some difficulty was experienced in the maintenance of the Essex roads owing to the lack of railway transportation for the conveyance of granite and the small quantity possible of delivery as compared with requirements. The railway strike of September, 1919, imposed an additional strain upon the roads at a time when they were least able to stand it. Several of the Essex roads suffered to such an extent that complete reconstruction will be necessary, one of such roads being the one from London to Ipswich, running through the center of the county. To restore this road alone, which is but 33 miles in length, an expenditure of £132,000 will be necessary, it is estimated, exclusive of the cost of repair to damaged bridges.

As an indication of the traffic carried by some of these roads during the railway strike, statistics taken in November, 1919, show that on one occasion, about 2 a. m., a fleet of 39 loaded trucks, representing 585 tons, passed an observation post on the Chelmsford-Colchester road at intervals of 45 seconds.

PENNSYLVANIA AUTOMOBILE REGISTRATIONS DURING 1920.

Figures made public recently by the State Highway Department of Pennsylvania show that a total of 1,069,603 1920 automobile licenses of all sorts have been issued. The figures show that there was an increase in almost all classes of registrations. Comparative tables are as follows:

COMPARISON OF AUTOMOBILE REGISTRATIONS IN 1919 AND 1920.

Registrations plates.	1920	1919
Passenger cars	507,622	429,001
Commercial vehicles	50,226	40,406
Tractors and traction engines	3,160	3,328
Trailers	839	1,291
Motor cycles	23,510	25,123
Motor vehicle dealers	13,761	9,935
Tractor dealers	231	188
Motor-cycle dealers	241	(1)
Bicycles with motor attached	1,128	(1)
Total	600,723	509,272
LICENSES ISSUED.		
Motor vehicle licenses, all kinds	600,723	509,272
Paid drivers	114,345	82,343
Licensed operators	128,291	146,282
Tractor drivers	368	(1)
Transfer of licenses	40,736	31,463
Special operators	466	(1)
Learners, permit	2,487	(1)
Vendee affidavits secondhand cars	180,653	16,344
Dealers in used motor vehicles	1,534	951
Total	1,069,603	786,590

[1] Classifications as required by new motor law after Jan. 1, 1920.

The decrease in the number of licensed operators is attributed to the fact that all owners of motor vehicles are now given an operator's license free of charge, while persons not owners pay a fee. Department officials are unable to explain the apparent decrease in the number of motor cycles during 1920. There is also a decrease in the number of traction engines and trailers.

The number of paid drivers' licenses kept step with the increase in the number of passenger and commercial vehicles.

That many automobiles change hands during the course of the year is evidenced by the large number of vendee affidavits relative to used cars, of which during the first nine months in 1920 there were 180,000.

The law compelling the filing of affidavits relative to secondhand cars was not in effect during all of 1919.

EDUCATIONAL CONFERENCE ON HIGHWAYS AND TRANSPORTATION.

IN spite of the enormous increase in the demand for better highways and motor vehicles caused by the recent rapid extension of motor transportation, it is claimed that the engineering schools of the country are annually furnishing only a small percentage of the number of trained men required by the industry. To supply this lack, the Commission on Highway and Highway Transport Education, which has been called together under the direction of P. P. Claxton, National Commissioner of Education, is formulating a plan to furnish the universities with facilities for putting into operation the recommendations of leading highway and transportation experts.

At the University of Pittsburg, where the commission has met twice to date, a study of automotive and highway problems has been a feature of the engineering course for several years. The university is among the first in the country to maintain a laboratory for the study of automotive engineering. More recently a new building, now virtually completed, has been constructed at the university which combines under one roof laboratories devoted to the study of automotive engineering and highway testing. This is a new departure in the field and is in line with the policies which the Commission on Highways and Highway Transportation Engineering Education hopes to promote.

It is believed that other universities will follow this lead, and that the shortage of trained engineers for the work will be eliminated quickly. The commission's plans, although still in the process of formation, will no doubt call for the incorporation of the study of the rules of the road and similar elementary transportation features into the curricula of high schools and grade schools. Courses of study will be planned for collegiate institutions and the plans include also the extension of the idea to vocational schools. All this, of course, is to be done for the better preparation of engineering students who are to undertake the nation's transportation problems, the solution of which is felt to be of as great importance to a rapidly growing industrial and commercial people as any in the country's history.

The members of the commission, in addition to Mr. Claxton, are Dean Bishop, of the University of Pittsburg; Roy D. Chapin, president of the Hudson Motor Car Co.; Walter C. John, specialist in land grant statistics of the Bureau of Education; T. H. MacDonald, chief of the Bureau of Roads; Paul D. Sargent, president of the American Association of Highway Officials; H. S. Firestone, of the Firestone Tire Co.; and C. J. Tilden, professor of Engineering Mechanics at Yale University.

BUREAU ASSISTS IN CAR ALLOCATION.

AFTER the issuance of Order No. 7 by the Interstate Commerce Commission providing for preferential treatment in the use of open-top car equipment for the movement of coal, a hearing was held by the commission beginning on July 8 and extending three days, at which representatives of the railroads, the coal interests, and the shippers of sand, gravel, and similar material were given an opportunity to state their support of or opposition to the order and the continuance of any policies of priorities or embargoes. At this hearing Mr. Daniel B. Willard, chairman of the Advisory Committee of Railway Executives, stated that in his judgment the railroads should endeavor to move road materials for maintenance purposes and for completion of important contracts under construction. He also stated that close working arrangements should be perfected between the shippers and railway officials for the purpose of obtaining all the benefits possible from close cooperation. This latter position was indorsed by Chairman Clark of the commission in his final statement of the conference. Later, in testifying before the Committee on Reconstruction and Production, of which Senator Calder is chairman, in New York on August 12, Mr. Willard again took a similar position that the railroads should endeavor to transport necessary material for the completion of important road projects which are now already begun. In order to accomplish these ends the Bureau of Public Roads has been working in close cooperation with the State highway departments and the Car Service Commission of the American Railroad Association. In cases where cars can not be secured for shipping materials needed for the completion of important road projects or for the maintenance of highways, through the ordinary channels, a plan is being followed by which applications for cars are forwarded to the Car Service Commission. The bureau is assisting the Car Service Commission in passing on these permits by furnishing information as to the importance and status of the road projects for which the applications for the movement of materials are made.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN JULY, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	75	Wilcox and Marengo	12.420	Gravel	July 9	$206,873.48	$103,436.74
	76	Sumter	17.386	do	July 14	304,223.68	152,111.84
Arizona	31	Maricopa		Bridge	July 9	50,006.00	25,003.00
	32	do		do	July 10	45,440.34	22,720.17
	33	do	6.751	Bitulithic or concrete	July 14	239,229.87	119,614.93
Arkansas	104	Faulkner	5.480	Macadam	July 15	60,360.30	21,000.00
	108	Benton	39.940	Gravel	do	130,634.57	58,800.00
	88	Pike	27.380	do	July 10	188,210.60	82,855.59
	85	Conway	11.430	Macadam	July 15	126,260.14	40,000.00
	102	Faulkner	6.860	do	July 14	76,644.37	25,000.00
	103	do	4.810	do	July 15	52,321.83	20,000.00
	63	White	11.010	Gravel	do	99,195.25	36,300.00
	71	Crittenden	7.520	Gravel macadam	July 9	94,043.40	35,000.00
	80	Arkansas	15.540	Macadam surface	July 15	355,267.11	63,750.00
	99	Mississippi	14.330	Gravel	July 9	147,966.50	50,000.00
	109	Baxter	6.820	Macadam surface	July 21	54,506.85	20,000.00
	84	Conway	1.270	Bituminous macadam	July 13	[1] 5,445.51	
	67	Dallas	2.060	Gravel	July 16	[1] 3,089.62	
California	60	Mono	13.410	Earth	July 13	161,678.00	80,839.00
Colorado	61	Butte		Bridge	July 9	462,000.00	231,000.00
	123	Garfield and Eagle	6.941	Earth	July 3	97,110.72	48,555.36
	106	Routt	1.354	Gravel	July 9	28,182.81	14,091.40
	80	do	6.629	Earth	July 12	58,197.86	29,098.93
	116	El Paso	4.439	Gravel	July 14	103,284.20	51,642.10
	47	do	1.855	do	July 21	39,053.85	19,526.92
	52	Teller	4.924	Earth	do	24,265.94	12,132.97
	75	Grand	7.000	do	July 16	25,553.16	12,776.58
	113	Chaffee	4.498	do	July 20	73,509.57	36,754.78
	128	Rio Blanco	3.000	Shale	July 21	18,332.60	9,166.30
	74	Moffatt	6.500	Gravel	July 27	73,691.34	36,845.67
	58	Powers	1.747	do	July 9	[2] 11,195.14	[2] 5,597.57
Georgia	138	Warren	9.000	Sand-clay	do	66,297.24	33,148.62
	140	Hancock	11.000	do	July 8	46,791.04	23,395.52
	160	Houston		Bridge	July 9	48,973.10	20,000.00
	164	Macon		do	do	27,024.80	12,000.00
	148	Baron	4.617	Sand-clay	do	68,623.50	25,000.00
	141	Richmond	12.000	do	do	47,041.96	23,520.98
	155	Elbert	8.000	do	do	60,060.00	30,000.00
	167	Fulton	2.500	Concrete	do	83,776.00	37,500.00
	173	Schley	2.500	Sand-clay	July 12	23,295.19	11,647.54
	134	Coweta	19.850	Topsoil	July 10	270,362.40	50,000.00
	139	Taliaferro	5.500	Sand-clay	July 9	31,307.79	12,000.00
	169	Clinch	8.000	Topsoil	July 10	33,654.50	15,000.00
	171	Calhoun		Bridge	July 12	41,063.00	15,000.00
	172	Baldwin		do	July 9	42,464.92	12,000.00
	116	Walton	7.130	Topsoil	July 10	59,314.98	29,657.49
	161	Richmond	2.600	Bridge	July 9	71,032.01	35,516.00
	163	Stewart	1.750	Sand-clay	July 10	33,262.13	12,500.00
	51	Colquitt	3.340	Paved	July 9	[1] 61,536.62	[1] 30,768.31
	102	Cobb	4.000	Pavement	July 22	[3] 79,817.65	[3] 39,908.82
	166	Dougherty	2.000	Paved	July 15	77,693.00	15,000.00
	168	Jefferson	10.000	Sand-clay	July 12	33,967.42	16,983.71
	175	Wilkinson	2.800	do	July 14	22,034.99	10,000.00
	176	Lincoln	5.000	do	July 15	29,149.78	12,000.00
	174	Campbell	2.000	Paved	July 20	63,227.45	27,500.00
	165	Polk	6.500	Sand-clay	July 14	42,450.65	14,225.32
	44	Hall	11.410	Topsoil	do	[2] 45,655.02	[2] 22,827.51
	106	Sumter	2.000	Bituminous surface	July 16	[2] 79,972.42	[2] 48,984.08
	69	Franklin	8.055	Topsoil	July 15	[1] 38,100.66	[1] 19,816.58
Idaho	30	Power	19.200	Gravel	July 6	159,863.00	79,931.50
	19	Bonner	16.700	Crushed rock	July 9	167,999.61	83,999.80
	49	Ada	1.500	Bituminous concrete	July 20	29,981.60	14,990.80
Iowa	48	Fremont	1.070	Gravel	July 28	45,445.84	17,000.00
	134	Worth	8.500	do	July 14	83,751.25	41,800.00
	32	Des Moines	2.070	Paved	July 9	[2] 198,619.85	
	51	Guthrie	2.670	Earth	July 15	[2] 100,340.90	
Kansas	60	Anderson	7.500	Gravel	July 9	268,290.00	75,500.00
	61	Lima	7.750	Macadam	do	230,263.00	75,000.00
	62	Morris	6.500	do	do	274,748.10	97,000.00
	64	Neosho	5.500	Gravel	do	120,254.75	60,127.37
	63	do	5.000	do	July 12	95,342.50	47,671.25
	59	Douglas	11.000	Concrete	July 10	439,120.00	165,000.00
	65	Allen	2.000	do	July 30	94,641.80	30,000.00
Kentucky	33	Boyd	1.100	Rock asphalt	July 12	25,599.20	12,799.60
	34	Webster	10.300	Earth	do	141,644.25	70,822.12
	31	Meade	13.830	do	July 17	160,215.00	80,107.50
	35	Boyd	16.140	Brick and bituminous surface	July 21	534,957.72	267,478.86
	36	Grant	3.980	Bituminous and concrete	July 30	142,303.76	71,151.85
Louisiana	50	Lafourche	10.350	Gravel	July 12	96,190.76	48,095.38
	55	Jefferson Davis	19.430	do	July 9	216,163.20	108,081.60
	68	Caddo	9.500	do	July 12	371,447.73	185,723.86
	30	Allen	10.240	Sand-clay or gravel	July 15	119,647.66	35,550.00
	74	Iberia	4.600	Gravel	July 21	67,090.65	33,545.32
	73	Richland	31.150	do	do	579,337.66	209,607.61
Massachusetts	40	Worcester	1.012	Concrete	July 6	40,491.00	20,240.00
	43	do	.625	do	July 9	65,202.50	12,500.00
	44	Hampshire	6.566	Bituminous macadam	do	327,827.50	159,700.00
	42	Berkshire	2.291	Macadam	do	104,720.00	45,820.00
	39	do	7.923	Bituminous macadam	July 13	294,390.80	147,195.40
	41	Middlesex	1.250	Gravel	do	24,944.70	12,472.35
Michigan	46	Charlevoix	11.000	do	July 12	209,990.00	104,995.00
Minnesota	198	Hennepin	1.420	Concrete	do	88,139.31	4,900.00
	186	do	3.800	Asphaltic	July 15	245,871.89	15,293.20
	187	Carlton	1.310	Gravel	do	12,624.70	6,312.35
	185	Jackson	6.000	Gravel	July 15	48,510.00	24,255.00
	103	Renville	10.820	Concrete, brick, asphaltic	July 7	[1] 49,419.92	[2] 5,023.30

[1] Revised project statements. Amounts given are decreases from those in the original statements.
[2] Revised project statement. Amounts given are increases from those in the original statements.
[3] Canceled or withdrawn.

PROJECT STATEMENTS APPROVED IN JULY, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost	Federal aid.
Mississippi	31	Alcorn	3.250	Gravel	July 27	$52,635.00	$23,500.00
	98	Madison	9.800	Earth	...do	74,426.99	37,213.49
Missouri	124	Barry	5.500	Gravel	July 8	43,494.00	21,747.00
	89	Laclede	8.780	...do	...do	53,563.62	26,781.81
	121	Barry	9.900	Macadam	...do	67,711.20	33,855.60
	131	Pettis	10.800	...do	...do	140,400.00	70,200.00
	132	Henry	6.100	Gravel	July 9	60,023.99	30,011.99
	110	Phelps	15.700	...do	...do	83,057.72	41,528.86
	100	St. Clair	7.720	...do	July 15	38,600.00	19,300.00
	126	Audrain	3.800	...do	July 10	62,666.18	31,333.09
	129	Wayne	31.000	...do	July 12	110,979.00	55,489.50
	133	Henry	8.100	...do	...do	82,475.00	41,237.50
	134	Stone	7.210	...do	...do	18,355.32	9,177.66
	105	Iron	28.500	...do	July 10	243,633.15	121,816.57
	109	Texas	28.000	...do	...do	85,100.00	42,550.00
	128	Henry	8.000	Earth	...do	34,800.00	17,400.00
	103	Montgomery	13.000	...do	July 15	46,198.90	23,099.45
	107	Iron	13.000	Concrete and gravel	...do	116,205.63	58,102.81
	130	Harrison	22.200	Earth	...do	288,642.20	144,321.10
	101	Madison	24.680	Gravel	July 14	137,659.50	68,829.75
	111	Ozark	40.700	...do	July 21	80,840.00	40,420.00
	125	Daviess	8.880	Earth	July 14	139,664.83	69,832.41
	127	Henry	6.600	Chert	...do	105,600.00	52,800.00
	136	Callaway	1.000	Gravel	July 21	30,000.00	15,000.00
	144	...do	15.700	...do	July 20	70,343.73	35,171.86
	115	Dallas	16.300	...do	July 28	39,300.00	19,650.00
	140	...do	4.840	...do	...do	15,840.00	7,920.00
	92	Laclede	12.570	...do	July 30	63,577.80	31,788.90
	97	Callaway	18.000	Gravel and macadam	...do	146,800.00	73,400.00
	112	Dallas	8.300	Gravel	July 28	28,293.20	14,146.60
	119	Miller	18.750	...do	...do	136,824.49	68,412.24
	143	Morgan	20.000	...do	July 30	68,139.99	43,069.99
	145	Barry	4.000	...do	...do	15,999.99	7,999.99
	150	Green	31.500	Macadam and gravel	...do	157,500.00	78,750.00
	151	Barry	4.500	...do	...do	22,400.00	11,200.00
Montana	94	Meagher	14.000	Earth	July 12	96,514.34	48,257.17
	98	Flathead	4.000	Gravel or rock	July 10	19,974.68	9,987.34
	123	Stillwater	8.300	Gravel	July 13	55,526.39	27,763.19
	129	...do	1.162	...do	July 9	19,656.03	9,828.01
	90	Sanders	8.000	...do	July 15	43,975.20	21,987.60
	96	Pondera	22.390	...do	...do	198,779.67	99,389.83
	115	Wheatland	10.000	...do	July 9	69,740.00	34,870.00
	99	Flathead	4.500	...do	July 15	19,904.50	9,952.25
	114	Rosebud	10.950	...do	...do	54,430.49	27,215.24
	121	Dawson	.456	Concrete	July 14	55,639.16	8,837.95
	125	Sweet Grass		Bridge	July 15	15,997.30	7,998.65
	78	Granite	11.500	Gravel	July 20	75,942.35	37,971.10
	88	Sanders	4.250	...do	July 14	39,633.47	19,816.73
	131	Missoula	7.000	...do	July 21	91,850.00	45,925.00
	133	Sweet Grass	5.980	...do	...do	49,440.16	24,720.08
	108	Musselshell	18.000	Topsoil	July 27	100,442.10	50,221.05
	2	Wibaux	2.220	Gravel	July 9	[1] 26,246.22	[1] 13,123.11
	46	Jefferson	3.500	Earth	July 6	[2] 22,000.00	[2] 11,000.00
	97	Broadwater	2.980	Gravel	July 15	[1] 11,824.26	[1] 5,912.11
	132	Hill	20.000	...do	July 28	101,283.60	50,641.80
	118	Lincoln	4.000	Earth	July 30	19,998.00	9,999.00
Nebraska	143	York, Fillmore, and Polk	39.300	...do	July 15	150,579.00	75,289.50
	157	Butler and Seward	24.800	...do	...do	95,964.00	47,982.00
	151	Lancaster	.596	Brick	July 14	41,420.50	10,474.55
	155	Lancaster and Sanders	13.300	Earth	...do	60,643.00	30,321.50
	153	Cass	34.000	...do	...do	130,020.00	65,010.00
	159	Fillmore	6.900	...do	July 16	26,807.00	13,403.50
	160	Brown	15.000	Sand-clay	...do	92,224.00	46,112.00
	161	Saline	17.600	Earth	July 21	79,706.00	39,853.00
	163	Keyapaha	9.000	Sand-clay	July 16	54,694.20	27,347.10
	44	Sherman	3.500	Earth	July 31	[2] 8,085.00	[2] 4,042.50
	59	Wheeler	8.000	Earth and sand-clay	...do	[2] 42,398.40	[2] 21,199.20
	61	Blaine	9.400	...do	...do	[2] 46,750.00	[2] 23,375.00
	62	Thomas	4.800	...do	...do	[2] 22,330.00	[2] 11,165.00
	80	Grant	13.200	...do	...do	[2] 44,105.60	[2] 22,052.80
	99	Thomas	14.800	...do	July 13	[2] 59,778.40	[2] 29,889.20
Nevada	28	Douglas	1.170	Concrete	July 28	51,739.93	23,400.00
New Hampshire	123	Hillsborough	.280	Gravel	July 12	8,000.00	4,000.00
	93	Belknap	.875	Macadam	July 9	12,600.00	6,300.00
	111	Carroll	3.040	Gravel	...do	42,000.00	21,000.00
	116	...do	.937	...do	July 13	11,999.99	5,999.99
	120	...do	6.600	...do	July 10	80,000.00	40,000.00
	122	Cheshire		Bridge	...do	17,000.00	8,500.00
	119	...do	.448	Bituminous macadam	July 12	15,000.00	7,500.00
	124	Belknap	1.260	...do	July 15	18,035.67	9,017.83
	121	Sullivan	1.140	Gravel	...do	20,000.00	10,000.00
New Mexico	51	Socorro	10.500	...do	July 28	52,514.00	26,257.00
	52	...do	11.300	Rock	...do	70,466.00	35,233.00
New York	71	Fulton	3.500	Bituminous	July 15	140,000.00	70,000.00
	68	Otsego	2.820	Concrete	July 14	147,000.00	51,450.00
	73	Madison and Oneida	10.480	Reinforced concrete	...do	545,300.00	190,855.00
	25	...do	5.700	Concrete	July 3	[2] 151,470.00	[2] 75,735.00
	10	Rockland	2.470	Bituminous macadam or concrete	May 28	[2] 49,399.35	[2] 24,699.67
	20	Delaware	5.100	Bituminous macadam	...do	[2] 118,400.00	[2] 59,200.00
	21	Rockland	1.450	Concrete	...do	[2] 52,200.00	[2] 26,100.00
	42	Delaware	5.750	...do	...do	[2] 230,000.00	[2] 115,000.00
North Carolina	129	Richmond	16.700	Sand-clay	July 15	105,985.00	52,992.50
	78	Rutherford	36.000	Topsoil and gravel	July 17	91,790.60	45,895.30
	38	Caswell	6.800	Topsoil	July 21	[1] 68,053.45	[1] 5,563.64
	124	Surry	18.000	...do	July 27	[2] 141,644.80	[2] 70,822.40
	140	Robeson	38.500	Sand-clay	...do	[2] 312,950.00	[2] 156,475.00
North Dakota	107	Grand Forks	6.000	Gravel	July 6	38,541.53	19,270.76
	106	Pierce	7.375	Earth	July 12	30,250.00	15,125.00
	108	Griggs	17.000	...do	July 30	84,370.00	42,185.00
	109	...do	16.000	...do	...do	72,170.00	36,355.00

[1] Revised project statements. Amounts given are increases from those in the original statements. [2] Canceled or withdrawn.

PROJECT STATEMENTS APPROVED IN JULY, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost	Federal aid.
Ohio	117	Cranford	4.080	Brick or asphalt	July 12	$219,000.00	$50,000.00
	151	Clermont	5.489	Macadam	...do	189,700.00	88,000.00
	140	Huron	3.110	Brick	July 9	132,600.00	28,700.00
	166	Brown	3.240	Waterbound macadam	...do	89,000.00	33,000.00
	168	Highland	2.240	Macadam	July 15	88,300.00	14,000.00
	130	Montgomery	3.250	Kentucky rock asphalt	July 12	137,000.00	38,000.00
	152	Coshocton	4.043	Monolith brick or concrete	...do	192,000.00	57,000.00
	163	Richland	3.301	Concrete or bituminous macadam	...do	169,000.00	33,000.00
Oklahoma	33	Choctaw	57.000	Crushed lime rock	...do	660,385.70	330,192.85
	41	Bryan	56.000	Crushed rock	...do	900,000.00	450,000.00
	29	Cotton	2.153	Concrete	July 9	185,366.00	43,053.00
	35	Adair	8.000	Gravel	...do	36,334.20	18,167.10
	36	Latimer	3.000	Burnt shale	July 12	40,000.00	20,000.00
	47	Johnston	20.000	Gravel	July 13	249,816.60	124,908.30
	34	Ottawa	2.500	...do	...do	40,150.00	20,055.00
	19	Oklahoma	13.500	Paved	July 15	540,000.00	270,000.30
	37	Atoka	1.000	Gravel	July 14	16,000.00	8,000.00
	32	Wagoner	18.500	...do	July 20	233,600.00	116,800.00
Oregon	46	Malheur	0.891	Bituminous or concrete	July 12	27,066.60	13,533.30
	41	Gilliam	6.900	Broken stone or gravel	July 10	171,132.50	85,566.25
South Carolina	38	Oconee	18.367	Topsoil	July 8	200,056.88	56,179.54
	77	York	1.544	Concrete	...do	68,282.50	10,000.00
	61	Darlington	19.676	Sand-clay	...do	144,530.17	50,000.00
	68	Chester	9.147	Topsoil	July 15	73,341.59	35,000.00
	80	Williamsburg	11.027	Sand-clay	...do	113,703.11	56,851.55
	96	Anderson	8.550	Concrete and topsoil	July 9	115,926.69	57,963.34
	69	Chester	6.137	Topsoil	July 12	95,405.13	25,000.00
	71	York	6.520	...do	July 10	45,343.83	14,000.00
	92	Union	6.227	...do	July 15	32,921.57	7,414.19
South Dakota	56	Sully	13.100	Gravel	July 12	74,662.28	37,331.04
	54	Grant	6.000	...do	...do	46,623.50	23,311.75
	61	Brule and Aurora	12.800	Earth	...do	63,316.00	31,658.00
	63	McPherson	16.450	...do	...do	79,321.00	39,660.50
	59	Fall River	5.530	Gravel	July 21	91,722.40	45,861.20
	60	Pennington	9.400	...do	...do	76,472.00	38,236.00
Tennessee	11	Union	9.040	Gravel	July 20	[3] 41,283.00	[3] 16,412.70
	20	Fentress	14.322	Macadam	July 8	273,221.44	136,610.72
	22	Weakley and Carroll	14.540	Bituminous macadam	July 12	481,498.54	240,749.27
	47	Rutherford	16.360	...do	July 13	420,524.64	210,262.32
	50	Lincoln	15.284	...do	...do	642,253.51	321,126.30
	46	Dickson	9.940	Waterbond macadam	July 14	195,300.78	96,719.51
Texas	179	Ellis	11.500	Crushed stone	July 12	208,530.30	75,000.00
	165	Webb	30.000	Gravel	...do	258,797.86	88,492.88
	166	Atascosa	13.470	...do	July 10	285,733.22	142,866.61
	168	Robertson	18.000	...do	July 12	141,626.65	69,262.60
	169	Dickens	7.540	...do	July 9	36,040.34	18,020.17
	170	Fort Bend	13.170	Bituminous	July 12	248,654.94	50,000.00
	171	Hunt	11.140	Macadam	July 10	305,967.24	76,491.81
	174	Randall	17.100	Earth	...do	28,191.43	14,000.00
	175	Matagorda	10.100	Shell	July 12	53,290.02	26,634.22
	176	Runnels	5.700	Gravel	July 9	44,234.91	22,117.45
	192	Harrison	24.560	...do	July 15	205,750.60	100,000.00
	172	Lamar	4.850	...do	July 9	167,160.08	83,580.04
	150	Jasper		Bridge	July 15	59,996.11	25,000.00
	183	Gonzales	28.200	Gravel	...do	278,219.89	113,750.00
	158	Hemphill	14.440	Sand clay	...do	79,931.98	39,965.99
	177	Hays	17.050	Crushed stone	...do	64,682.11	30,000.00
	188	Hunt	10.790	Gravel, surface treated	...do	298,430.46	106,914.23
	134	Polk	17.930	Bituminous	July 13	[1] 100,618.39	[1] 25,154.60
	189	Hunt	8.690	Bituminous surface	July 15	205,498.37	68,499.46
	190	...do	3.460	...do	...do	120,237.17	48,094.87
	182	Taylor		Bridge	July 14	66,139.70	33,069.85
	173	Travis	6.100	Gravel, bituminous surface	July 27	74,214.95	37,107.47
	184	Falls	0.768	Gravel	July 15	16,504.80	8,252.40
	181	Johnson	13.000	...do	July 28	276,159.40	100,000.00
	195	Falls	7.000	Gravel, bituminous surface	...do	148,819.00	70,000.00
	180	San Patricio	27.557	Gravel	July 30	349,392.79	174,696.39
	187	Bastrop	27,293	...do	...do	191,078.60	95,539.30
Utah	93	Cameron	14.721	Concrete	July 21	[2] 417,415.51	[2] 233,333.33
Vermont	14	Boxelder	0.404	Paved	July 10	9,357.37	4,678.68
Virginia	17	Windsor		Bridge	...do	10,730.50	5,365.25
	64	Norfolk and Nansemond	8.000	Concrete	July 12	319,352.00	159,676.00
	83	Pittsylvania	2.990	Bituminous macadam	July 16	80,865.40	40,432.70
Washington	59	Snohomish		Bridge	July 8	23,622.50	11,811.25
	75	Okanogan	4.140	Gravel	...do	29,994.36	14,997.18
	73	Pacific	7.630	Earth	July 15	279,974.64	138,000.00
	74	Skagit		Bridge	...do	19,800.00	9,900.00
	65	Okanogan	1.990	Gravel	July 21	35,841.19	15,000.00
	76	Pierce	0.500	...do	...do	34,667.60	12,750.00
West Virginia	98	Randolph	4.500	Macadam	July 13	88,281.60	39,040.00
Wisconsin	120	Trempealeau	7.150	Gravel	July 9	125,802.79	46,548.54
	134	Juneau	5.280	Topsoil	...do	41,864.69	18,000.00
	166	Langlade	7.570	Earth	...do	36,667.51	15,500.00
	114	Oconto	4.880	Gravel	July 10	45,915.98	17,000.00
	105	Monroe	3.750	Shale	July 13	36,230.73	11,700.00
	179	Waukesha	5.860	Concrete	July 14	275,082.58	77,000.00
	125	Taylor	4.510	Earth	July 27	41,941.36	15,000.00
	176	Sauk	1.310	Gravel	July 30	22,056.30	9,378.00
Wyoming	80	Hot Springs		Bridge	July 13	89,100.00	44,550.00
	91	Platte	15.100	Select material	July 19	137,720.00	68,860.00
	90	Hot Springs	3.228	...do	July 14	37,785.00	18,892.50
	94	Park		Bridge	July 22	14,630.00	7,315.00
	72	Big Horn	0.664	Select material	July 28	22,110.00	11,055.00
	97	Sweetwater	1.818	Earth	July 27	12,760.00	6,380.00

[1] Revised project statements. Amounts given are decreases from those in the original statements.
[2] Revised project statements. Amounts given are increases from those in the original statements.
[3] Canceled or withdrawn.

PROJECT AGREEMENTS EXECUTED IN JULY, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Colorado	68	Rio Grande	11.358	Gravel	June 30	$84,459.47	$42,229.73
Georgia	91	Lowndes	4.920	Paving	July 9	170,437.45	85,218.72
Illinois	1-20	Whiteside	2.072	Concrete	July 2	80,737.96	40,368.98
	7LU	La Salle	4.134	Earth	...do....	140,602.98	69,541.65
	10EFG	Will	21.072	Concrete	...do....	824,246.56	405,026.37
	11R	Vermillion	4.848	Concrete and brick	...do....	103,536.84	51,768.42
	5EM	Peoria and Marshall	.....	Concrete	...do....	[1] 128,446.23	[1] 59,680.88
	5 (BC) D (G-15-d)	....do	.....	....do	...do....	[1] 184,701.42	[1] 81,660.00
	1-14	Whiteside	.....	....do	...do....	[1] 6,188.76	[1] 3,094.38
	1-15	....do	.....	....do	...do....	[1] 16,309.40	[1] 8,154.70
	1-10, 11,16	....do	.....	....do	...do....	[1] 31,789.78	[1] 15,894.88
Kansas	40GHI	Crawford	2.981	Mono brick or concrete	July 8	242,460.37	44,722.50
Maine	7	Aroostook	3.500	Gravel	July 13	84,099.95	42,049.97
	24	....do	3.310	....do	...do....	68,871.33	34,435.66
Michigan	43AB	Muskegon	13.956	Concrete	July 9	574,433.34	284,744.85
	3	Baraga	.....	Earth	July 12	[1] 265,879.12	[1] 116,512.44
Minnesota	86	Aitkin	10.480	Gravel	July 30	57,030.05	25,000.00
Mississippi	81	Bolivar	4.470	Concrete	June 30	80,393.16	40,151.58
	80	Adams	.....	Gravel	...do....	[1] 2,576.62	[1] 1,288.31
Missouri	38	Lewis	8.371	....do	July 13	133,317.15	66,658.57
Nebraska	49A	Thurston and Dakota	11.243	Earth	July 31	101,063.10	50,531.55
	82A	Garden	8.670	Sand-clay	...do....	100,802.39	50,401.19
	84A	Greeley	6.603	....do	July 30	47,658.66	23,829.33
	87A & B	Madison	11.140	Gravel	...do....	49,186.77	24,593.38
	88B	Dodge and Cuming	1.011	Sand gumbo	July 31	9,800.95	4,900.47
	107A	Cass, Lancaster, Saunders	8.230	Earth	...do....	45,379.77	22,689.88
	123	Richardson	1.477	Sand-clay	July 30	69,744.07	34,872.03
	130A	Cheyenne	12.040	Earth	...do....	72,051.85	36,025.92
	112	Douglas	16.690	....do	July 31	86,941.97	43,470.98
	55A	Saline	1.050	....do	July 30	9,804.13	4,902.06
	64A	Pierce	9.608	....do	...do....	64,305.50	32,152.75
	76A	Dawes	14.530	....do	...do....	115,253.64	57,626.82
	17	Lancaster	.....	....do	...do....	[1] 21,697.52	[1] 5,022.66
	34A	Garfield	.....	Sand-clay	...do....	[1] 11,054.58	[1] 5,527.29
	35A	Douglas	.....	Earth	...do....	[1] 3,126.83	[1] 1,563.41
	66	Cherry	.....	Sand-clay	July 31	[1] 5,745.08	[1] 2,872.54
	71	Franklin	3.130	Earth	...do....	[2] 35,673.89	[2] 17,836.94
	98	Saline and Lancaster	.....	....do	July 30	[1] 1,502.14	[1] 751.07
	115	Platte	0.797	Concrete	July 31	[2] 40,707.63	[2] 15,940.00
North Carolina	13	Wayne	12.573	Topsoil	July 29	101,467.96	50,733.98
	57	Rowan	7.205	Topsoil and concrete or other hard surface.	...do....	77,168.57	38,584.28
	59A	Columbia	11.025	Topsoil	...do....	88,464.64	44,232.32
	62	Buncombe	3.430	Bituminous macadam	...do....	139,191.32	69,595.66
	61A	Brunswick, New Hanover	2.179	Concrete	...do....	118,690.00	43,580.00
	67A	Nash	.....	Asphalt or concrete	July 31	[1] 9,803.86	[1] 4,901.93
	92	Surry	.....	Topsoil	...do....	[1] 27,118.41	[1] 13,559.20
	91	....do	.....	....do	July 29	[2] 12,190.84	[2] 6,095.42
	76	Cabarrus	.....	Concrete	...do....	[1] 5,950.56	[1] 2,683.40
	19	Rockingham	.....	Topsoil	July 31	[1] 4,956.96	[1] 6,785.50
	44	Granville	.....	....do	July 29	[1] 5,863.80	[1] 10,188.71
	47	Guilford	.....	Bituminous surface	...do....	[1] 21,584.12	[1] 10,792.06
	50	....do	.....	....do	July 31	[1] 19,109.37	[1] 9,554.69
	51	....do	.....	Bituminous concrete	July 29	[1] 20,801.20	[1] 10,400.60
	54	Wake	.....	Warrenite	...do....	[1] 15,438.95	[1] 7,719.48
	55A	Mecklenburg	.....	Bituminous concrete or cement and macadam base.	...do....	[1] 60,325.57	[1] 30,162.78
	29	Union	.....	Topsoil	...do....	[1] 9,413.91	[1] 4,706.95
	63	Buncombe	0.073	Penetration macadam	July 31	[1] 34,388.23	[1] 11,424.05
	67B	Nash	0.006	Topeka or concrete	...do....	[1] 13,160.67	[1] 3,344.45
	74A	Stanly	.....	Topsoil	...do....	[1] 535.15	[1] 267.57
	39	Union	.....	Topsoil and bituminous macadam	...do....	[1] 34,872.09	[1] 17,436.05
	72A	Anson	3.896	Topsoil	July 29	70,470.89	35,235.44
	77	Rutherford	2.206	Concrete	...do....	100,159.44	44,120.00
	80A	Montgomery	16.528	Topsoil	July 31	185,823.02	92,911.51
	94A	Mitchell	5.036	Rock asphalt	July 29	131,796.39	65,898.19
	109	Burke	3.584	Topsoil	...do....	55,191.64	27,595.82
	111	Forsyth	12.086	....do	...do....	65,278.45	32,639.22
	74B	Stanly	4.919	....do	July 31	63,411.26	31,705.63
Oklahoma	15	Washington	12.780	Concrete	July 9	500,000.00	250,000.00
	21	Mackintosh	21.787	Concrete and gravel	...do....	482,376.86	232,705.03
	22	Comanche	5.950	Gravel	...do....	75,561.92	37,780.96
	24	Garfield	7.164	Bituminous concrete	...do....	368,205.19	168,416.48
	25	Kingfisher	1.357	Concrete	...do....	56,774.32	27,140.00
	27	Kay	1.712	....do	...do....	68,600.31	34,235.79
South Carolina	41	Hampton	15.625	Sand-clay	July 8	134,313.93	44,817.39
	53	Charleston and Colleton	.....	Bridge	...do....	69,740.83	34,870.41
	36	Chesterfield	11.346	Sand-clay and topsoil	June 30	81,511.98	24,000.00
	48	Georgetown	16.849	Sand-clay	June 29	146,148.36	73,074.18
Utah	6	Grand and San Juan	.....	Earth	July 6	[1] 159,305.16	[1] 79,652.58
Virginia	40	Dinwiddie	.....	Concrete	May 18	[1] 1,576.69	[1] 788.34
West Virginia	70	Grant	8.630	Earth and water-bound macadam	July 28	59,900.00	29,950.00
	93	Monongalia	2.120	Reinforced concrete	July 30	102,829.03	31,120.00
	36	Upshur	3.080	Concrete	...do....	118,036.00	45,845.00
	55	Tyler	1.184	Bituminous macadam	...do....	36,000.00	18,000.00
	75A & B	Calhoun	4.470	Earth	...do....	62,564.00	31,282.00
	81	Taylor	1.553	Concrete	...do....	62,080.00	31,040.00
	83	Lewis	2.000	Brick on concrete base	...do....	122,000.00	40,000.00
	87	Mason	4.400	Gravel	...do....	57,955.38	28,520.00
	88	Wayne	2.600	Earth	...do....	55,773.85	25,770.00
	91	Barbour	2.000	Bituminous macadam	...do....	55,680.00	27,840.00
	94	Fayette	5.200	....do	...do....	74,565.00	33,480.00
	96	Nicholas	2.210	Earth	...do....	49,000.00	24,500.00
	21	Lewis	.....	Brick	...do....	[1] 1,321.20	[1] 3,670.00
	24	Preston	.....	Bituminous macadam	...do....	.....	[1] 8,000.00
	25	Lincoln	.....	Concrete	...do....	[1] 47,440.99	[1] 17,954.34
	47	Wetzel	.....	....do	...do....	[1] 53,930.00	[1] 26,965.00
Wyoming	52	Fremont	.....	Topsoil	July 9	37,654.76	18,827.38

[1] Modified agreements. Amounts given are increases over those in the original agreemeuts.
[2] Modified agreements. Amounts given are decreases from those in the original agreements.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States, 1914. A Summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
691. Typical Specifications for Bituminous Road Materials.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and classification of Rocks for Road Building, including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
77. Experimental Roads in the Vicinity of Washington, D. C.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918.
Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D–2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D–3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D–4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D–6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D–8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 5, D–12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 10, No. 7, D–13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D–15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D–16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 29. WASHINGTON, D. C. SEPTEMBER, 1920

PENNSYLVANIA FEDERAL-AID PROJECT NO. 12, FROM BANGOR TOWARD EASTON

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page

Improving Improved Roads Now the Word in Maryland 3
J. N. Mackall

State Highway Mileage and Expenditure in 1919 9
A. P. Anderson

Highway Administration and Road Conditions in Canada 13

Character of Federal-Aid Roads Consistent with Traffic Demands . . . 17

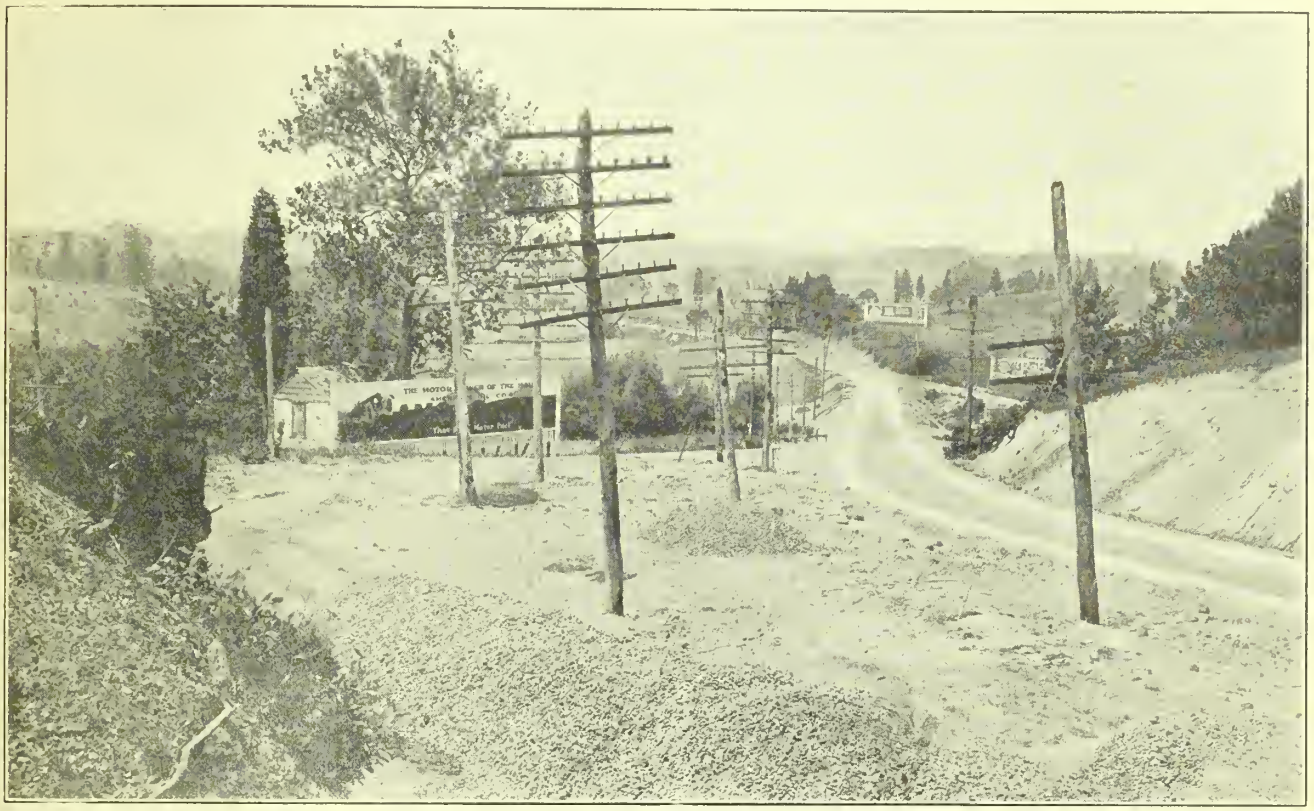
Highways in the High Schools 20

Federal-Aid Allowances 23

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

IMPROVING IMPROVED ROADS NOW THE WORD IN MARYLAND.

By J. N. MACKALL, Chairman, Maryland State Roads Commission.



FAMOUS DEADMAN'S CURVE ON THE MARYLAND ROAD BETWEEN WASHINGTON AND BALTIMORE IS NOW AS SAFE AS ANY OTHER SECTION OF THE STATE'S ROAD SYSTEM.

WHY should it be necessary to improve improved roads? Naturally, that is the first question which must arise in the mind of the reader. What policy of road construction has made it necessary to improve roads already improved? Maryland's experience in road construction provides a striking answer to these questions. It is the belief of the writer that the policy of so improving roads that later they will require further improvement is fundamentally sound and correct. Indeed, it is probably to this policy that Maryland owes her position as one of the foremost good road States of the Union.

In 1908, on the advice of the late Gov. Austin L. Crothers, Maryland embarked on a program of extensive highway improvement. Five million dollars was appropriated for the purpose, a sum which at that time appeared so large that many people throughout the State believed that the height of extravagance had been reached. The development of automobile traffic was then in its early stages. The policy of licensing the motor vehicles for road maintenance had been entered upon only a short time before, and the ideas which then prevailed as to the future development of motor traffic are well illustrated by a passage from the message of Gov. Crothers to the legislature, advocating the license fee. He recommended the creation of a motor vehicle department, the licensing of automobiles, and then added this very illuminating remark, "In time, it is probable that the revenue from this source will reach $100,000 per year". In 1920, twelve years from that time, it amounts to approximately $2,500,000. But to have embarked at that time on the construction of a system of roads designed to accommodate an automobile traffic which would yield annually in license fees the present return of $2,500,000, when the most enlightened imagination could only conceive that in time it would reach $100,000 proportions, would have entailed a burden of cost which could never have been met, because sentiment could not have been created for the financing of any such program. The commission, therefore, it seems to the writer, very wisely adopted a policy of building roads as good as the tax-payer was willing to pay for, roads which would meet reasonably well the traffic of the time and

of the immediate future, leaving the unforseen future to care for itself.

LOW COST OF EARLY ROADS.

The average cost of the roads built from that first appropriation was less than $10,000 per mile. In some cases the work entailed considerable grading and drainage, but in others it amounted simply to resurfacing the old turnpikes, which had already been graded and drained, which kept the average cost down to the low figure of $10,000. Generally speaking, the roads built at that time were of macadam 12 feet in width, and 6 inches in thickness, but the width was soon increased to 14 feet. If roads 18, or even 16 feet in width, of some such material as bituminous macadam had been built at that time, it is not improbable that the public would have become alarmed at the tremendous cost, and long ago ceased to continue appropriations for road building. It is interesting to note, therefore, that the commission's policy of building low-type roads met with the uniform commendation of all the people of the State, and every successive legislature since 1908 has made additional appropriations for road building.

A COMPLETED SYSTEM FOR $30,000,000.

To date there has been spent in excess of $30,000,000 for a system of improved roads. All county seats and all towns of 1,000 people or more are connected by good roads, which enable the farmer to haul his produce to market, and the city man to send his product to the farmer. Her roads explain why Maryland has taken the lead among all the States in the development of rural motor truck express service. They have brought general prosperity to the State. Maryland people are firm in their belief that they have earned their cost, and if they require rebuilding to-day, the State is better able to rebuild them now than it would have been to have gone without them.

The point is that the perfect maintenance which all the roads of the system have received from the day they were completed, and the systematic scheme of gradual improvement which is now being worked out will enable many of the roads to give satisfactory service for years to come, and they will give that service at much less expense than the cost of roads of higher type at the present time.

IMPROVING THE ROADS.

Striking examples of the improvements which are fitting these roads to carry the increased modern traffic are to be found on the main road between Philadelphia and Washington through Baltimore. The section between Belair and Washington, a distance of more than 50 miles, has been widened from 12 and 14 feet to 20 feet, by the construction of concrete shoulders on each side of the existing macadam, and in the process of widening the crown of the road has also been made to conform to modern standards. The old roads had a crown of three-quarters inch to the foot, which made the sides so steep that the traffic was forced to cling to the center of the road, because to get on the sides meant sliding to the shoulder and gutter. All traffic, therefore, concentrated in the center, except that as the volume of traffic increased it was necessary to pass other vehicles more frequently, which meant going over to the side, and "chewing" off the edge of the macadam. The concrete shoulders have been so constructed as to remedy this condition as well as to widen the road.

The surface of the shoulders is about 2 inches lower than the center of the road, and from 2 to 5 inches higher than the old surface of the macadam adjacent to the shoulders. The road surface has been brought up to the height of the shoulders by the addition of a wedge of bituminous macadam material which has a depth of from 2 to 5 inches adjacent to the concrete, and tapers off to a featheredge at 2 to 6 feet from the shoulder.

WIDENED ROADS GIVE SATISFACTION.

This unusual construction has given eminent satisfaction. No difficulty whatever has been experienced in keeping the macadam in place. The concrete on the side prevents the spreading disintegration of the macadam, and the macadam is thickened on the edges where it is normally weakest. Some of these sections have since been surface treated over the entire width, and it is impossible now to tell which part of the surface is the original macadam, and which is the section filled in. The method of treatment enabled traffic to use the road at all times during construction, and best of all resulted in a road surface which is satisfactorily carrying the heaviest of modern traffic without abandoning a dollar's worth of the original construction.

NEW ROADS BUILT WITHOUT DETOURS.

The principle of improving the roads of the system without interruption to traffic is one to which we try to adhere in all of our work, even when the old road is to be entirely reconstructed. When the new section of road is to be of concrete, we have adopted the plan of building the surface in two longitudinal sections with a joint running along the center. This form of construction was used on parts of the Washington-Baltimore road, several sections of which were completely destroyed during the spring of 1918. One half of the 20-foot roadway was constructed at a time, allowing the traffic to use the other half of the road simultaneously with construction, first on the old roadbed, then on the new concrete. The two

IN MARYLAND WIDE CONCRETE ROADS ARE BUILT IN TWO LONGITUDINAL SECTIONS WITH A JOINT IN THE CENTER. TRAFFIC IS NEVER TURNED OFF THE WAY DURING CONSTRUCTION.

THE INSIDE BANK IS CUT DOWN TO PROMOTE "VISIBILITY." IT IS LEFT HIGHER THAN THE ROAD, SO MACHINES WILL NOT HUG THE NEW BANK AND LOSE THE BENEFIT OF THE IMPROVEMENT.

CONCRETE SHOULDERS AND GUTTER AND EARTH EMBANKMENTS ON THE OUTSIDE OF THE CURVE ARE MAKING MARYLAND ROADS SAFE AND ADEQUATE. WHITEWASHED BOULDERS AND TREES BY THE ROADSIDE MARK THE WAY FOR THE TRAVELER AFTER DARK.

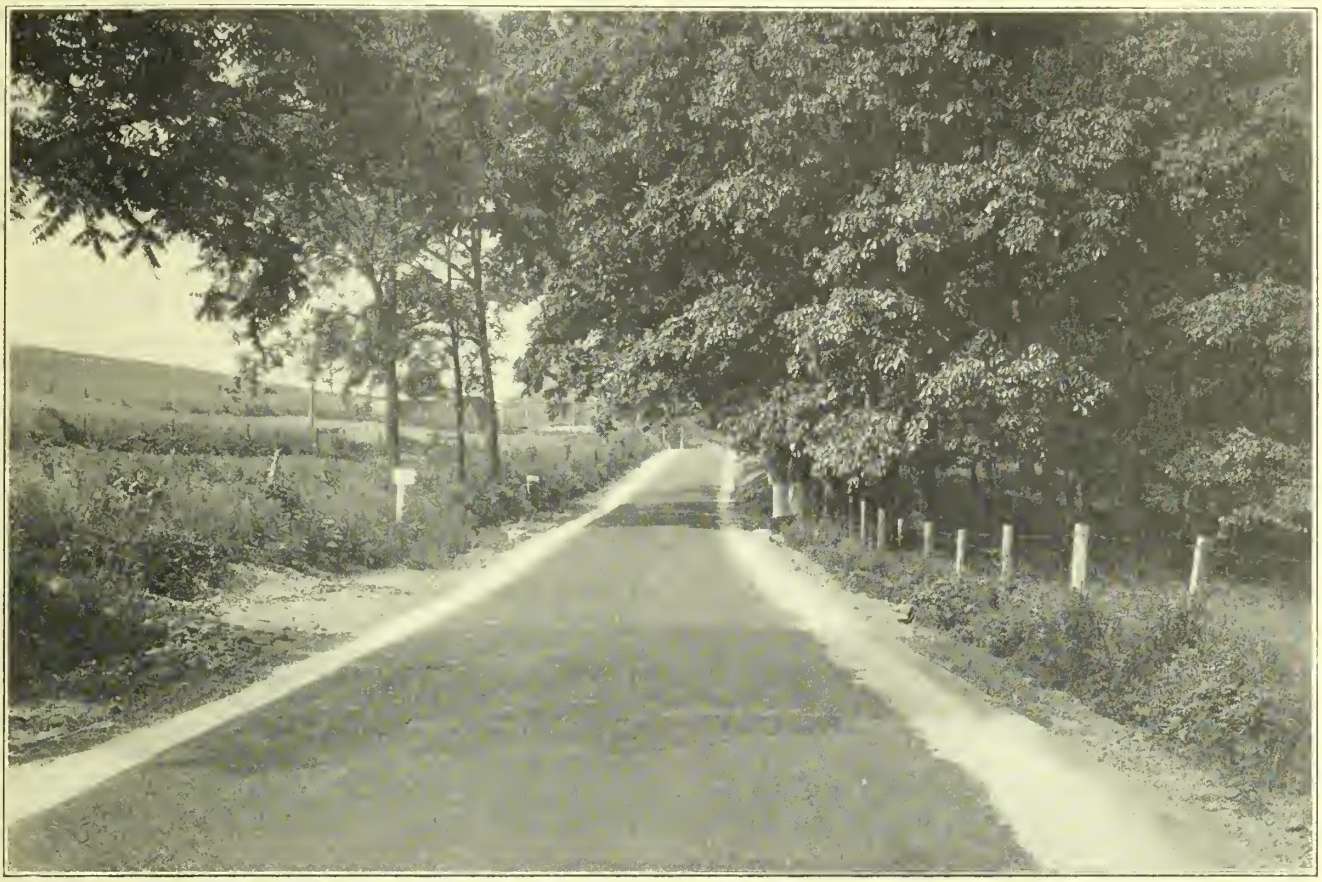
sections were tied together with ¼-inch round rods, 4 feet long with one-half their length in each half of the pavement. They were spaced 2 feet center to center along the road.

Some difficulty was experienced at first in keeping the traffic from running against the projecting rods before the second section was laid; but this was overcome by laying old railroad ties or sticks of wood along the edge of the concrete to protect them. There has been no difficulty in maintaining the joint in the center of the road, as the 20-foot width permits traffic to travel on each side of the road instead of in the center. In fact the joint has been of considerable advantage in an entirely unexpected way, in that it has apparently tended to divide the two streams of traffic and keep each to its proper side of the road. So satisfactory have been the results in this respect on this section of road, that we have drawn a black line down the center of other concrete roads of this width to serve the same purpose.

DANGEROUS DEAD MAN'S CURVE IMPROVED.

In addition to widening and thickening the roads the commission is taking every opportunity to eliminate dangerous curves and grades, or to treat them in such a way as to remove the danger. One of the most dangerous curves in the State was the famous "Dead Man's Curve," south of Elkridge, between Baltimore and Laurel. Hundreds of automobiles have been wrecked at this point, and there is a record of more than 30 deaths. The photograph on page 3 shows the road as improved, and also traces of the original location which lay to the left of the telephone poles. The high bank which shows at the right of the picture formerly extended to the left nearly to the line of poles and completely obscured the view around the sharp curve at the top of the hill. The danger was increased by the steep grade. While the relocation does not make the road straight, it reduces the curvature at each end of the reverse curve to 9°, and affords a sight ahead for more than 300 feet at all points in both directions. No accidents, serious or otherwise, have come to our attention since the curve was flattened, and it is apparently eliminated as a source of danger. The cost was $17,000, a considerable sum to spend on less than a quarter of a mile of improved road, other than for ordinary maintenance. Yet when we consider the toll of human lives and wrecked machines which has been taken at this point the cost seems small indeed.

Another place which was especially dangerous was the Winter's Run hill south of Belair. While not as many deaths occurred at this point, the wreckage of automobiles was greater than at Dead Man's Curve.



THE SURFACE-TREATED MACADAM ROADS OF MARYLAND WIDENED WITH CONCRETE SHOULDERS ARE GIVING EMINENT SATISFACTION. AT NIGHT THE WHITE MARGINS ADD GREATLY TO THE SAFETY OF TRAVELERS.

SUCH CURVES AS THIS TOOK HEAVY TOLL IN WRECKED MACHINES BEFORE THEY WERE "BANKED." NOT AN ACCIDENT HAS BEEN REPORTED IN THE TWO YEARS SINCE THE IMPROVEMENT WAS MADE.

The grade on this hill is 6 per cent, but the alignment is a series of reverse curves on the side of a hill. The total length of the dangerous section on both sides of the run involves approximately a mile. It was impossible on account of the grades to straighten the line on this road, but the "inside" of all curves was excavated to approximately 4 feet above the crown of the road for a sufficient distance to permit the driver of a machine to see at least to the next curve from 300 to 400 feet ahead, and the material so excavated was deposited on the "outside" of the curves so that vehicles would not skid over the bank.

It was felt that to excavate these banks to the grade of the road would defeat the purpose in view, which was to hold the traffic out from the bank a sufficient distance to permit drivers to see around it, and if the curves had been excavated to the grade of the road, traffic would unquestionably have "hugged" the bank, and made the place as dangerous as ever. The material deposited on the outside of the curves was placed along the shoulder, and for a height of at least 4 feet on a slope next to the road of about 1 to 1. The shoulders were surfaced over to the bank on the inside and on the outside the pavement was raised to extend up to the artificial embankment, thereby giving a superelevation sufficient to compensate for the curvature. The cost of this work was approximately $10,000, and in this case, as at Dead Man's Curve, there has not been an accident of any kind which has come to the attention of the commission since the improvement was completed, now nearly two years ago. Numerous other curves have been treated in a similar manner, but to a very much less degree than at this point.

MACADAM ROADS GIVE SPLENDID SERVICE.

Macadam roads, a number of which are only 6 inches in thickness, except on the very heavy traffic streets, have given splendid satisfaction, and are rendering a road service equal to that rendered by much more expensive highways in other sections of the country, but this service is only rendered by continuous, perfect maintenance at all seasons of the year. Perfect is probably a rather strong term, yet it is the only word which expresses the writer's idea. No hole of any size is permitted to remain in the surface of any road. A patrol system which works with the smoothness of a well-oiled machine is responsible for this condition. Holes can be repaired as soon as they appear, or before they appear, only by the patrolman, so the patrolman has been impressed with the fact that perfect maintenance on low-grade roads can only be brought about by the patrol system. If these roads are not patrolled and perfectly maintained, in an incredibly short time they become worn out, and soon impassable, as is demonstrated by numerous sections of roads built in the State by the counties, and maintained, or rather not maintained by them.

The macadam roads in particular must be surface-treated with the best material obtainable, a material which will render the surface at all time impervious to water, yet, one which will not cause the surface to roll, become wavy, and soon go to pieces. The accomplishment of this is not entirely a matter of the selection of the bituminous material and the application of it,but also the selection and application of the mineral aggregate covering.

COARSE STONE USED FOR SURFACE TREATMENT.

The commission has successfully used naphtha cut-back asphalt, water-gas tar, and coal-gas tar, so that it is not limited to any one bituminous material, but it does use a very large mineral aggregate covering in large quantities, and has it thoroughly rolled into the the surface. The specifications now require material to be free from dust, and to pass through a revolving screen having circular openings 1¼ inches in diameter. Of course, a material of this size could not be used because of the damage to tires, unless it were immediately and satisfactorily rolled into the surface. The commission, therefore, insists that from one to two rollers be used with every distributor, and on the Frederick Road out of Baltimore, during 1920, five rollers worked 16 hours per day with two distributors. It is necessary that these chips be rolled into the surface and be kept rolled into place until the material has set up. Sand or small chips have a tendency to form a mat on the surface, which invariably pulls off, or waves, whereas the larger chips are pressed down into the surface and "key" together the new and previous applications. On roads which have been treated for a number of years, an application of only from one-fourth to one-fifth gallon of bitumen to the square yard is used, and from 100 tons to 120 tons of stone chips to the mile for a 15-foot macadam road. There is great danger in too heavy or too frequent use of surface treatments. Applied too often or too heavily the bituminous material forms a mat of considerable depth on the surface. In warm weather, and under heavy traffic, the mat begins to move and makes a very wavy surface, and it has been demonstrated conclusively that the use of heavy trucks on a wavy surface very soon causes the road to break through. A comparatively smooth surface is absolutely essential to the maintenance of any road subjected to truck traffic.

STONE PILES AT ROADSIDE FOR MAINTENANCE.

Another requirement, and a very important one for adequate maintenance of macadam roads, is to have along the road at convenient points, for use of the patrolman, material for patching any holes as soon as they develop. Especially is this necessary in the spring. In a climate such as Maryland's, the roads are frequently covered with snow for a month or two during the winter, and the use of trucks and motor cars with chains form ruts in the surface, which must be patched as soon as the road thaws out in the spring. It is, therefore, absolutely necessary that material for this patching be delivered on the road in the fall. The need for early spring patching has eliminated from consideration as a patching material any emulsions

(Concluded on page 19.)

STATE HIGHWAY MILEAGE AND EXPENDITURES IN THE YEAR 1919

By ANDREW P. ANDERSON, Highway Engineer.

DURING the calendar year 46 States of the Union expended a total of over $400,000,000 on their rural roads and bridges. This total is made up of the actual cash expenditures for such items as labor, materials, supervision and administration, amounting to $389,455,931, and convict labor and statute labor, the value of which is not definitely known but which is estimated at about $12,000,000. So far as possible all expenditures on city streets within incorporated towns and cities and all items of sinking-fund payments or the redemption and interest payments on road and bridge bonds have been excluded.

The road and bridge expenditures for 1919 show an increase of approximately 33⅓ per cent over those of 1918 and 70 per cent over those of 1914. More striking, however, is the increase in the proportion of the total funds supervised by the several State highway departments. In 1918 the expenditures by or under the supervision of the State highway departments amounted to $117,285,268, while the local road funds, over which they exercised no control whatever, amounted to $168,812,925. In 1919, however, the State highway departments supervised the expenditure of $200,292,694 as against the total of $189,163,237 expended by the local road and bridge authorities.

The year 1919 was one of unusual activity in practically all lines of highway work. During the war all work of this nature had been curtailed in every possible way, often to the great inconvenience of the public. Consequently, at the close of hostilities road activities soon began to claim their full share of public attention. In fact, in every State ambitious plans were immediately mapped out and definite action to secure their approval was begun.

PROVIDING ROAD FUNDS.

The first and most striking development in this movement related to the provision of adequate funds. Between November 1, 1918, and December 31, 1919, State highway bonds amounting to a grand total of $234,800,000 were voted as follows:

Illinois	$60,000,000
Michigan	50,000,000
Pennsylvania	50,000,000
California	40,000,000
Oregon	12,500,000
Maine	10,000,000
South Dakota	4,500,000
Utah	4,000,000
Wyoming	2,800,000
Nevada	1,000,000

13283—20——2

The voting of State highway bonds, however, was not confined to the year 1919. On February 16, 1920, the voters of Alabama ratified a State highway bond issue of $25,000,000 and in June the State of Oregon ratified a constitutional amendment increasing the maximum tax rate, thereby approving an additional bond issue of $10,000,000. The Legislative Assembly of Maryland during the regular session also provided for the issue of $3,000,000 of State highway bonds.

As a part of this movement eight other States made definite provisions for submitting to a vote of the electors at the general election in November, 1920, the issue of State highway bonds as follows:

Minnesota	$75,000,000
Missouri	60,000,000
West Virginia	50,000,000
Washington	30,000,000
Montana	15,000,000
Colorado	5,000,000
Idaho	2,000,000
New Mexico	2,000,000
Total	239,000,000

The State of Florida will also vote on the question of amending its constitution so as to permit the legislature to issue highway bonds in an amount not to exceed 5 per cent of the assessed valuation of the State. Kansas and Virginia will vote on removing constitutional barriers toward still greater State participation in road work.

Only two States have defeated by a vote of the electors the question of issuing State highway bonds during the period November 1, 1918, to October 1, 1920. On May 6, 1919 the electors of the State of Oklahoma defeated a proposed bond issue for $50,000,000, and on November 4, 1919, the electors of the State of Texas defeated a bond issue for $75,000,000.

During 1919 the Federal Government also made liberal provisions for continuing Federal-aid road work in cooperation with the several State highway departments. The Post Office appropriation act of February 28, 1919, carried an amendment to the original Federal-aid road act of July 11, 1916, amplifying somewhat its terms and providing an additional appropriation of $200,000,000 for post roads and $9,000,000 additional for forest roads. Of the post road appropriation, $50,000,000 was made immediately available and $75,000,000 available for each of the fiscal years 1920 and 1921, while the forest road appropriation was made available at the rate of

$3,000,000 for each of the fiscal years 1919, 1920, and 1921. This amendment also provided for the transfer to the Secretary of Agriculture of all available war materials, equipment, and supplies suitable for use in the improvement of highways which were not needed by the War Department. All equipment and material so transferred was to be distributed on a value basis—the same as provided in the original Federal-aid road act—among the highway departments of the several States, to be used on roads constructed in whole or in part by Federal aid.

about 223,000 miles were earth or graded roads. The 7,212 miles of earth road construction is divided among a large number of States, while the earth mileage maintained is located mainly in the states of Iowa, New York, Kansas, Missouri, and Oklahoma. In the States of Iowa and New York, the State highway departments have fairly definite supervision or control over all rural road work within the State, whether construction or maintenance.

The public rural roads of the United States as determined in 1914 had a total length of 2,478,552 miles,

TABLE 1.—ROAD AND BRIDGE EXPENDITURES, 1919.

State.	Source of funds expended under supervision of State highway departments.				Distribution of expenditures.						State funds available, 1920 (approximate)	Local road and bridge expenditures, 1919, not under State highway department (approximate).
					Construction.		Maintenance roads and bridges.	Engineering.	Administration.	Equipments, miscellaneous.		
	Federal.	State.	Local.	Total.	Roads.	Bridges.						
Alabama	$284,430.88	$65,002.60	$262,979.91	$612,413.39	$501,374	$51,129	.....	$36,358	$20,008	$3,543	$2,000,000	$1,200,000
Arizona[1]	66,738.99	1,451,336.71	(4)	1,518,075.70	1,023,215	33,920	$86,381	140,152	49,520	184,887	1,250,000	2,500,000
Arkansas	76,874.27	585,193.00	6,218,972.63	6,881,040.00	6,496,100	(3)	.....	341,900	93,040	.....	407,847	2,500,000
California	498,795.45	6,568,093.39	79,999.91	7,146,888.75	4,772,924	(3)	1,363,901	488,195	249,083	272,786	10,000,000	[4]12,350,569
Colorado	20,000.00	1,775,000.00	500,000.00	2,295,000.00	1,020,000	(3)	1,000,000	80,000	65,000	130,000	2,200,000	2,000,000
Connecticut[5]	(12)	2,293,397.11	92,536.69	2,385,933.80	828,466	360,500	931,383	70,235	81,574	113,776	4,000,000	1,458,033
Delaware	(6)	1,147,080.26	646,464.70	1,793,544.96	1,638,227	57,558	4,614	56,309	16,373	20,464	1,500,000	200,000
Florida	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Georgia	426,704.47	.....	490,710.13	917,414.60	653,658	217,886	.....	45,870	(7)	.....	1,50 ,000	6,000,000
Idaho	410,000.00	850,000.00	540,000.00	1,800,000.00	1,095,000	118,000	176,000	283,000	48,000	80,000	1,000,000	2,500,000
Illinois	(12)	4,403,944.89	2,119,902.13	6,523,847.02	5,649,719	(3)	128,319	538,548	90,780	116,481	12,497,502	10,000,000
Indiana	236,288.89	400,691.10	565,000.00	1,201,979.99	995,221	10,000	.....	110,352	7,593	78,814	5,294,000	17,500,000
Iowa	.....	614,090.64	16,158,946.71	16,773,037.35	2,174,335	4,404,822	8,842,134	598,479	20,480	732,787	6,000,000	.....
Kansas[10]	187,586.63	47,500.00	458,046.80	693,133.43	575,213	70,420	.....	47,500	(7)	.....	60,000	10,334,363
Kentucky	226,395.00	926,200.00	650,713.75	1,803,308.75	1,460,430	(3)	.....	112,803	29,254	200,822	1,500,000	2,000,000
Louisiana	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Maine	65,011.60	1,739,118.72	970,374.32	2,774,504.64	1,491,937	327,953	790,701	76,623	46,981	40,309	3,594,000	1,750,000
Maryland	590,555.28	2,237,184.79	636,767.92	3,464,507.99	1,857,649	.....	1,464,867	96,995	22,809	22,189	2,900,000	3,500,000
Massachusetts	10,119.00	3,619,849.00	[2]580,915.00	4,219,883.00	1,181,172	(3)	2,228,706	259,902	63,242	486,861	6,920,227	6,005,000
Michigan	618,218.42	4,245,593.23	1,645,288.54	6,509,100.19	4,990,215	551,280	408,038	232,059	165,766	161,742	5,000,000	10,015,644
Minnesota	739,138.09	2,690,585.65	4,667,961.47	[8]8,097,685.21	5,129,769	806,925	1,582,834	538,967	39,190	.....	2,371,343	5,125,000
Mississippi[2]	98,000.00	40,000.00	252,000.00	390,000.00	350,000	(3)	.....	30,000	10,000	.....	.....	2,500,000
Missouri[2]	100,000.00	684,000.00	440,000.00	1,224,000.00	820,000	(3)	200,000	188,000	(7)	16,000	1,500,000	6,500,000
Montana	14,900.45	396,519.84	228,461.28	639,881.57	210,596	98,673	1,210	123,939	55,754	149,710	450,000	1,943,037
Nebraska	358,683.50	1,097,586.24	95,164.98	1,551,434.72	858,619	190,330	20,852	131,394	218,712	131,528	3,608,000	4,000,000
Nevada	179,685.15	342,250.48	105,428.10	627,363.73	442,034	38,426	29,330	46,338	59,185	12,050	500,000	275,000
New Hampshire	9,574.83	1,360,710.01	511,453.68	1,881,738.52	1,034,856	24,952	686,957	32,174	102,800	.....	2,262,003	1,000,000
New Jersey	(12)	6,320,000.00	9,000,000.00	15,320,000.00	5,500,000	30,000	9,210,000	200,000	230,000	150,000	7,200,000	(8)
New Mexico	39,739.12	839,053.56	330,473.32	1,209,266.00	602,784	183,462	201,180	22,700	15,900	183,240	1,800,000	375,000
New York	298,938.07	13,714,312.32	10,434,517.70	24,447,768.09	12,736.231	1,353,196	9,405,979	654,193	298,169	.....	34,775,667	.....
North Carolina[1]	254,731.89	1,010,442.76	452,170.22	1,717,344.87	1,158,015	(3)	144,632	199,838	82,945	131,915	1,750,000	5,000,000
North Dakota	250,000.00	233,128.47	500,000.00	983,128.47	578,741	(3)	[2]250,000	54,801	65,259	34,327	524,000	5,253,177
Ohio	694,921.36	4,603,771.72	5,414,645.28	10,713,338.36	8,236,769	326,196	1,562,359	436,559	151,455	.....	7,361,000	7,500,000
Oklahoma[2]	40,000.00	2,125,000.00	1,386,500.00	3,551,500.00	1,204,000	885,000	875,500	196,000	20,000	371,000	3,000,000	5,500,000
Oregon[9]	224,851.60	5,922,825.67	243,158.14	6,390,835.41	5,399,926	(3)	15,523	568,639	146,753	259,993	13,600,000	4,000,000
Pennsylvania	2,141,267.46	16,719,267.44	1,361,645.17	20,222,180.07	10,330,742	224,694	6,554,646	772,521	493,718	[11]1,845,859	25,000,000	8,000,000
Rhode Island	65,000.00	1,131,720.69	.....	1,196,720.69	725,810	85,545	280,044	66,707	7,500	31,114	1,485,000	650,000
South Carolina	246,024.08	80,406.25	268,343.57	594,773.90	458,195	56,172	309	58,815	12,594	8,688	756,060	1,840,000
South Dakota	94,247.41	319,225.91	117,195.84	530,669.16	396,448	(3)	.....	49,704	37,205	47,312	2,324,000	3,713,719
Tennessee[2]	82,857.91	794,464.09	90,888.52	968,210.52	481,000	100,000	225,811	80,700	80,700	.....	2,090,000	3,500,000
Texas	442,231.66	649,604.96	[13]3,000,000.00	4,091,836.62	3,974,275	(3)	.....	79,730	35,545	2,287	10,000,000	10,000,000
Utah	52,507.23	2,445,238.36	547,284.67	3,045,030.26	2,146,559	182,784	505,013	(3)	.....	210,674	1,500,000	2,500,000
Vermont	46,749.52	901,135.70	492,590.41	1,440,475.63	558,913	77,442	714,754	10,452	50,586	28,330	900,000	700,000
Virginia	146,906.64	2,262,192.18	980,836.01	3,389,934.83	1,832,745	123,442	1,120,198	109,037	42,581	161,933	4,941,260	1,750,000
Washington	616,687.30	2,894,969.96	415,355.41	3,927,012.67	3,289,557	350,000	.....	245,700	23,238	18,518	6,006,473	7,689,400
West Virginia	325,000.00	480,000.00	985,000.00	1,790,000.00	1,750,000	(3)	.....	40,000	(7)	.....	440,000	3,500,000
Wisconsin	204,962.44	3,062,638.89	6,689,434.07	9,957,035.40	1,551,684	1,348,918	1,854,523	100,496	101,414	.....	4,839,000	3,700,000
Wyoming	244,732.39	770,726.26	64,456.79	1,079,915.44	766,183	(3)	96,196	62,986	55,442	99,108	2,637,378	835,295
Total	11,730,056.98	106,861,052.85	81,701,583.77	200,292,693.70	115,929,306	12,689,626	52,962,894	8,715,670	3,456,149	6,539,047	211,244,760	189,163,237

[1] Fiscal year.
[2] Estimated by Highway Department.
[3] Included under Roads.
[4] Does not include San Francisco Co.
[5] Nine months only.
[6] Included under State.
[7] Included under Engineering.
[8] Included in State Funds.
[9] Eleven months only.
[10] Only 83 out of 105 counties shown.
[11] Includes $1,135,431.08 bonus for townships and $200,351.30 for purchase of turnpikes.
[12] Reimbursement for Federal-Aid work carried over to 1920.

WORK OF STATE DEPARTMENTS.

The several State highway departments during 1919 supervised the construction of 18,300 miles and the maintenance of 320,446 miles of public highways. Of the total mileage constructed, 7,212 miles, or nearly 40 per cent, consisted of grading or earth road construction, while of the 320,446 miles maintained under the supervision of the State highway departments of which 300,000 miles are now improved with some form of surfacing. A large portion of this mileage, however, is composed of sand-clay, gravel, or water-bound macadam, much of which is proving entirely inadequate for present-day traffic. That these facts are clearly recognized by the State highway departments is shown by the ever increasing total expenditures for high-grade construction, and while the work for the year 1919 shows a very large mileage of

grading or earth road most of this must be considered as preparatory to later surfacing.

The expenditures for 1919 by or under the various State highway departments are shown in Table 1, and the work accomplished is shown in Table 2. Table 3 shows the expenditures from purely State funds for the years 1904, 1914, 1917, 1918, and 1919, and also the total combined State and local expenditures for the same years. In Table 1 the columns under "Administration and engineering" show a considerable variation in the percentage devoted to these purposes in each of the several States. These variations are probably due more to differences in bookkeeping and the absence of any clear definition as to what items should be included under each of these heads than to any other cause. There is a great need for common standards in regard to these items, so that such expenditures may be fairly comparable as between the several States. This also applies to the term "Reconstruction and maintenance." In some States practically all reconstruction work is classed under "Maintenance," while in others it is classed entirely under "Construction," and in still others it is kept as a separate item and designated as "Reconstruction."

These compilations include no expenses for road or street work by the War or Navy Departments and similar agencies in or at military reservations or stations.

TABLE 2.—CLASSIFICATION OF ROAD MILEAGE SUPERVISED BY STATE HIGHWAY DEPARTMENTS, 1919.

State.	Kind of work.	Types.										Total rural road mileage 1914.	State.
		Earth or grading.	Sand clay.	Gravel.	Macadam.	Bituminous.	Concrete.	Brick.	Asphalt.	Miscellaneous.	Total.		
Alabama	Construction		$46.09	$31.55	$5.60				$1.00		$84.24	55,446	Alabama.
	Maintenance												
Arizona	Construction						$7.50		10.00	$52.50	70.00	12,075	Arizona.
	Maintenance									400.00	400.00		
Arkansas	Construction	$750.00		212.00	23.00	$24.00			26.00		1,035.00	50,743	Arkansas.
	Maintenance												
California	Construction	76.00					109.00		2.00		187.00	61,039	California.
	Maintenance	1,186.00			202.00	16.00	1,234.00		56.00		2,694.00		
Colorado	Construction	40.00		13.00	40.00		7.00				100.00	39,780	Colorado.
	Maintenance			15.00			5.00				20.00		
Connecticut	Construction										[1] 49.59	14,061	Connecticut.
	Maintenance	340.00	22.70	365.78	653.99	53.36	41.96	$0.64	32.40		1,510.83		
Delaware	Construction				2.00		28.50	2.42			32.92	3,674	Delaware.
	Maintenance						35.00	3.05			38.05		
Florida	Construction											17,995	Florida.
	Maintenance												
Georgia	Construction	21.00	70.00	2.40	1.60		13.70	3.00			111.70	80,669	Georgia.
	Maintenance												
Idaho	Construction	65.00		102.00		3.60					170.60	24,396	Idaho.
	Maintenance	381.00		174.00	17.00	2.00	3.00				577.00		
Illinois	Construction	83.00		3.50		4.50	167.00	5.50			263.50	95,647	Illinois.
	Maintenance	414.25		42.36	26.95	43.45	366.15	86.90			980.06		
Indiana	Construction					8.00	19.50	3.00			30.50	73,347	Indiana.
	Maintenance												
Iowa	Construction	372.83		296.99				4.10			673.92	104,074	Iowa.
	Maintenance	102,715.00		1,260.00			14.00	11.00			105,000.00		
Kansas	Construction			6.728			7.851	3.093			17.672	111,052	Kansas.
	Maintenance	30,974.00									30,974.00		
Kentucky	Construction	31.98		17.26	72.53	54.85	7.54	7.75	7.09		199.00	57,916	Kentucky.
	Maintenance												
Louisiana	Construction											24,563	Louisiana.
	Maintenance												
Maine	Construction	.53		201.43	.11	4.07	.71	.54			207.39	26,537	Maine.
	Maintenance									4,358.60	4,358.60		
Maryland	Construction	3.51					40.91				44.42	16,459	Maryland.
	Maintenance			146.57	904.14	34.21	285.21	1.76	4.50	64.83	1,441.22		
Massachusetts	Construction	2.10		26.19	1.64	90.48	8.98			19.29	148.68	18,681	Massachusetts.
	Maintenance	110.00		660.00	240.00	805.00	28.00			5.00	1,848.00		
Michigan	Construction	63.80		578.00	67.00	144.00	97.00	5.30			955.10	74,190	Michigan.
	Maintenance	225.30		4,717.00	581.00	1,750.00	324.00	7.20			7,604.50		
Minnesota	Construction	1,053.00		723.00			16.00		9.00		1,801.00	93,517	Minnesota.
	Maintenance	3,848.00	281.00	3,399.00	10.00	37.00	37.00	3.00	12.00	4,735.00	12,362.00		
Mississippi	Construction											45,779	Mississippi.
	Maintenance												
Missouri	Construction	300.00		82.90	20.00	7.80	6.50		2.70		419.90	96,041	Missouri.
	Maintenance										[2] 11,000.00		
Montana	Construction	15.00		55.00							70.00	39,204	Montana.
	Maintenance	50.00									50.00		
Nebraska	Construction	320.00		68.00			1.00	5.50			394.50	80,272	Nebraska.
	Maintenance	250.00	1.00					5.50			256.50		
Nevada	Construction	75.00		100.00			4.00				179.00	12,182	Nevada.
	Maintenance										[1] 300.00		
New Hampshire	Construction			98.40	2.42	1.06			5.66		107.54	14,020	New Hampshire.
	Maintenance										[2] 1,500.00		
New Jersey	Construction	.158		69.67	60.14	21.33	105.11			9.95	266.35	14,817	New Jersey.
	Maintenance									2,851.00	2,851.00		
New Mexico	Construction	403.00		424.00			5.00				832.00	43,091	New Mexico.
	Maintenance	2,140.00		860.00							3,000.00		
New York	Construction	9.32		333.00	906.23	245.67	318.52	.42		33.42	1,846.58	79,398	New York.
	Maintenance	58,817.00		7,211.00	9,544.00	3,185.00	622.00	288.00		333.00	80,000.00		
North Carolina	Construction	137.80			11.84	10.78	5.22		12.41		178.05	50,758	North Carolina
	Maintenance	1,052.10	2,139.50		155.80	43.90			47.90	1,363.70	4,802.90		
North Dakota	Construction	200.00									200.00	68,796	North Dakota.
	Maintenance	3,500.00									3,500.00		
Ohio	Construction	9.81			81.38	49.605	49.562	93.23	31.645	9.39	324.62	86,354	Ohio.
	Maintenance	3.12		148.22	1,427.22	54.96	400.53	710.44			2,744.49		
Oklahoma	Construction	1,752.00	200.00	40.00		4.50	3.25				1,999.75	107,961	Oklahoma.
	Maintenance	9,000.00	1,000.00	10.00							10,010.00		

[1] No definite data given as to types.

[2] Mostly earth roads.

TABLE 2.—CLASSIFICATION OF ROAD MILEAGE SUPERVISED BY STATE HIGHWAY DEPARTMENTS, 1919—Continued.

State.	Kind of work.	Types. Earth or grading.	Sand clay.	Gravel.	Macadam.	Bituminous.	Concrete.	Brick.	Asphalt.	Miscellaneous.	Total.	Total rural road mileage 1914.	States.
Oregon	Construction										[1] 544.00	36,819	Oregon.
	Maintenance												
Pennsylvania	Construction										[1] 253.10	91,556	Pennsylvania.
	Maintenance										9,493.00		
Rhode Island	Construction					8.20	2.20		9.70		20.10	2,170	Rhode Island.
	Maintenance				183.20	129.80	3.20		9.70		326.10		
South Carolina	Construction	9.70	55.00	4.50		2.14	8.08				79.42	42,226	South Carolina.
	Maintenance		18.00								18.00		
South Dakota	Construction										60.00	96,306	South Dakota.
	Maintenance												
Tennessee	Construction	13.60		14.90	11.60	2.50	4.40				47.00	46,050	Tenuessee.
	Maintenance	2,000.00		800.00	1,400.00	300.00					4,500.00		
Texas	Construction	19.80	260.00	844.42		197.50	40.85				1,362.57	128,960	Texas.
	Maintenance		109.63	198.02		75.70	4.20				387.55		
Utah	Construction	30.00				14.50	24.50				69.00	8,810	Utah.
	Maintenance												
Vermont	Construction			89.70	.67	1.00	.90			64.42	156.69	14,249	Vermont.
	Maintenance										[1] 4,378.00		
Virginia	Construction	37.34	163.79	41.81	77.23	6.40	9.26			11.71	347.54	53,388	Virginia.
	Maintenance	148.36	2,027.54	498.30	909.98	97.12	41.12			146.18	3,868.60		
Washington	Construction	174.20					59.50		1.00		234.70	42,428	Washington.
	Maintenance												
West Virginia	Construction	100.00		2.00		25.00	45.00	10.00	10.00		192.00	32,024	West Virginia.
	Maintenance												
Wisconsin	Construction	771.70	48.60	432.10	61.00	12.10	138.50	1.00		92.70	1,557.70	77,280	Wisconsin.
	Maintenance	3,603.00		1,402.00	791.00		158.00	12.00		34.00	6,000.00		
Wyomiug	Construction	271.00		120.62		1.25	13.00				405.87	14,797	Wyoming.
	Maintenance	1,082.00		120.00			500.00				1,702.00		
Totals and averages.	Construction	7,212.178	843.48	5,035.068	1,445.99	944.835	1,375.543	144.85	128.205	293.38	18,260.219	2,478,552	Totals and averages.
	Maintenance	222,839.13	5,599.37	22,027.25	17,046.28	6,627.50	4,102.37	1,129.49	162.70	14,291.31	320,446.400		

[1] No definite data given as to types.

TABLE 3.—CASH ROAD AND BRIDGE EXPENDITURES FOR CALENDAR YEARS 1904, 1914, 1917, 1918 AND 1919.

State.	Year in which first State-aid law passed.	State funds expended by or under State highway department. 1904	1914	1917	1918	1919	Total cash expenditure from all sources (approximate). 1904	1914	1917	1918	1919
Alabama	1911		$170,232	$89,511	$103,285	$65,003	$378,040	$3,949,019	$2,669,022	$2,371,214	$1,812,413
Arizona	1909			543,422	975,802	1,451,337	67,591	982,721	1,569,422	2,017,750	4,018,076
Arkansas	1913		115,000	80,262	221,831	585,193	681,934	1,522,696	3,335,262	1,963,609	9,381,040
California	1895	$11,251		3,058,030	6,941,192	6,568,093	2,157,396	19,171,985	18,245,200	21,646,638	19,497,458
Colorado	1909		301,274	703,000	800,000	1,775,000	635,395	1,937,546	2,570,000	3,300,000	4,295,000
Connecticut	1895	219,165	1,307,381	2,197,264	3,172,706	2,293,397	1,195,125	3,640,963	4,004,225	5,018,820	3,843,967
Delaware	1903	14,000	31,000	21,600	429,734	1,147,080	90,803	511,628	321,600	943,377	1,993,545
Florida	1915			23,797	179,807	[2]	437,184	2,280,255	6,384,797	5,764,205	
Georgia	1908			1,910	15,000		894,936	3,688,172	4,318,350	5,792,056	6,917,415
Idaho	1905		49,812	473,132	491,342	850,000	201,648	1,371,469	2,092,723	3,519,920	4,300,000
Illinois	1905		387,989	1,258,338	860,911	4,403,945	3,844,424	8,734,713	10,083,728	10,183,353	16,523,847
Indiana	1917			14,000		400,691	3,438,389	14,233,986	14,014,000	13,000,000	18,701,980
Iowa	1904		74,000	89,787	113,488	614,091	2,344,107	10,187,567	15,625,406	14,549,622	16,773,037
Kansas	1911		9,080	10,000	25,000	47,500	692,823	5,544,048	6,010,000	5,018,117	11,027,496
Kentucky [1]	1912		18,000	1,501,650	1,000,000	926,200	1,161,194	2,474,621	4,923,651	3,380,000	3,803,309
Louisiana	1910		161,186	182,295	182,295	[2]	345,452	1,777,572	3,540,976	3,540,976	
Maine	1901	44,885	467,149	1,112,675	1,570,494	1,739,119	1,472,383	2,642,007	3,244,982	3,859,416	4,524,505
Maryland	1898		356,845	2,804,707	2,681,142	2,237,185	873,471	6,000,652	6,083,682	5,750,135	6,964,508
Massachusetts	1892	575,606	242,560	4,231,802	3,522,494	3,619,849	2,871,222	6,091,875	9,494,802	9,124,304	10,224,883
Michigan [1]	1905		657,264	1,704,359	1,704,359	4,245,593	1,816,504	9,261,998	11,190,153	10,673,153	16,524,744
Minnesota	1905		1,309,956	1,429,865	1,870,336	2,696,586	1,607,417	6,458,940	8,024,760	10,567,711	13,222,685
Mississippi	1915			6,500	10,000	40,000	339,669	3,960,377	3,256,500	760,000	2,890,000
Missouri	1907		277,253	367,913	704,400	684,000	1,570,801	5,513,049	7,374,933	7,154,400	7,724,000
Montana	1913		13,516	25,729	133,548	396,520	308,744	2,888,401	3,356,869	3,924,951	2,582,919
Nebraska	1911			9,500	201,202	1,097,586	494,886	1,796,278	4,603,400	3,855,829	5,551,435
Navada	1911			36,796	75,328	342,250	46,876	245,014	336,796	474,770	902,364
New Hampshire	1903	44,000	491,520	589,254	651,594	1,360,710	872,606	1,590,464	2,238,705	2,004,685	2,881,739
New Jersey	1891	250,000	1,306,596	1,501,902	1,848,932	6,320,000	3,274,811	7,208,287	6,280,897	6,708,933	15,320,000
New Mexico	1909		115,732	280,578	527,072	839,054	35,458	556,399	845,867	1,314,192	1,584,266
New York [1]	1898	1,056,460	8,544,126	9,432,679	9,432,679	13,714,312	3,937,729	23,231,964	21,685,131	20,715,131	24,447,768
North Carolina [1]	1901		5,000	20,000	20,000	1,010,443	624,381	5,215,491	5,520,000	4,020,000	6,717,345
North Dakota	1909			28,638	83,000	233,128	456,130	2,402,384	2,867,979	3,208,000	6,236,305
Ohio	1904		1,855,338	2,835,649	4,670,270	4,603,772	4,776,318	14,334,246	12,017,104	14,499,833	18,213,338
Oklahoma	1911			286,922	1,046,893	2,125,000	447,320	2,112,681	3,722,355	3,131,530	9,051,500
Oregon	1913		10,697	711,000	2,120,551	5,922,826	649,718	5,310,467	5,711,000	6,830,275	10,390,835
Pennsylvania	1903	127,767	1,976,768	4,351,566	8,041,834	16,719,267	4,887,266	10,424,580	11,463,333	14,753,876	28,222,180
Rhode Island	1902	79,397		486,725	745,674	1,131,721	376,812	446,496	861,725	1,135,672	1,846,721
South Carolina	1917			27,161	49,239	80,406	334,082	1,024,480	1,277,161	1,676,239	2,434,774
South Dakota	1911			5,000	30,473	319,226	268,723	1,217,809	2,755,000	3,031,709	4,244,388
Tennessee	1915			231,500	403,000	794,464	729,141	2,370,560	2,481,500	2,978,000	4,468,211
Texas	1917			10,000	295,567	649,605	2,543,613	9,920,079	10,010,000	11,325,727	14,091,837
Utah	1909		157,732	120,200	1,546,843	2,445,238	158,286	803,071	1,893,129	2,770,491	5,545,030
Vermont	1898	127,381	458,456	578,883	778,075	901,136	567,397	1,023,941	1,680,489	1,606,075	2,140,476
Virginia	1906		523,578	695,171	861,031	2,262,192	687,751	3,224,529	4,136,779	3,708,353	5,139,935
Washington	1905		1,343,431	2,031,392	2,922,436	2,894,970	1,344,842	7,944,717	7,115,691	7,256,306	11,616,413
West Virginia	1909				171,581	480,000	587,870	2,483,747	8,200,000	5,056,455	5,290,000
Wisconsin	1911		1,482,379	1,050,888	2,051,455	3,062,639	1,924,026	9,880,240	9,886,554	9,284,175	13,657,035
Wyoming	1911			37,845	67,582	770,726	74,476	669,661	589,691	929,215	1,915,210
Total		2,549,912	24,220,850	47,290,797	66,351,477	106,861,053	59,527,170	240,263,784	279,915,332	286,101,198	389,455,932

[1] Data for 1918 not available; State expenditures shown in 1918 column are for the year 1917.

[2] Data not available.

HIGHWAY ADMINISTRATION AND ROAD CONDITIONS IN CANADA.

THE previous articles in this series have entered upon a brief exposition of the character and relations of national and local governments in the country under consideration, and a comparison with corresponding American governmental units. A working knowledge of the powers and duties of the principal members of the governmental structure is, of course, essential to anyone who would understand clearly the methods of highway administration in vogue in a foreign country. The same method will be followed in this article, though, naturally, the more widespread understanding of Canadian institutions makes such a course less desirable in this article than in its predecessors which have dealt with France and England.

UNITS OF GOVERNMENT.

In all essential particulars the various Canadian governmental agencies have their exact parallels in the United States. The Dominion or Federal Government corresponds to the Government of the United States. The provincial governments of which there are nine correspond to our States. The Provinces in turn are divided into counties which differ from those in this country only in the detail that all cities and certain towns are not included under the jurisdiction of the county government. The townships into which the counties are divided are similar to the corresponding units here.

HIGHWAY ADMINISTRATION—NATIONAL, PROVINCIAL, AND LOCAL.

National.—As in the United States, the Federal or Dominion Government exercises no direct control over the construction and maintenance of highways, but in July, 1919, the Governor General assented to an act of Parliament known as the Canada highways act which provides that the Dominion Government may aid the Provinces in the construction and improvement of highways. Twenty million dollars was appropriated to be expended during a period of five years from April 1, 1919. The money is to be allotted to the Provinces in two ways, (1) $80,000 is to be paid each year to the government of each Province, (2) the remainder is to be allotted in proportion to population. The amount to be apportioned to particular highways is to be 40 per cent of the cost.

The rules and regulations established by the government provide that the highways to be aided must be main or market roads included in a five-year program of construction which must previously have been approved. The highways must be built in acordance with plans and specifications approved by the minister of railways and canals who is charged with the administration of the act; but the onus of supervision is placed upon the provincial highway department, which must also agree to maintain the roads constructed.

The methods of government control and the general nature of the cooperative arrangement are similar to those which exist in this country under the Federal aid act; indeed their system is patterned after ours in all essential details. The most important difference between the methods in the two countries is that the Canadians have no organization corresponding to our Federal aid district offices. It so happens that there is not the corresponding need for such agencies. The number of cooperating governmental units is only 9 instead of 48 as in the United States; and the 9 Provinces deal directly with the Dominion authorities at Ottawa.

The plan represented as great a departure from prevailing methods of highway administration as did the Federal aid plan in the United States; and the first year of operation has been devoted largely to the development of methods of cooperation. In this respect also the Canadian operations are following very closely the development of Federal aid in the United States. The organization and methods of procedure have by this time reached a workable stage, however, and it is expected that this year's work will show substantial beginnings of actual construction.

Up to June 1, eight of the nine Provinces had submitted program maps of the selected systems of highways. The total length of designated Federal aid roads was about 18,000 miles; and the sum of $73,000,000 was being raised by the several Provinces to be applied on this system during the next five years.

Provincial.—The extent of highway control exercised by the provincial governments is of two orders. In one group, which includes the Provinces of Prince Edward Island, Nova Scotia, New Brunswick, and British Columbia all roads are under the control of the central provincial government, both as to construction and maintenance. In the other five Provinces of Ontario, Quebec, Manitoba, Saskatchewan, and Alberta the counties or townships share in the control of certain highways to varying degrees.

Administration in British Columbia.—Taking British Columbia as a type of the Provinces which exercise complete control, the entire road system outside of

municipalities is administered by the provincial department of public works; at the head of which is the minister of public works, who is also a member of Parliament. Under the minister is a deputy minister who is a permanent official, not subject to removal with changes of administration. The roads branch of the public works department is controlled directly by a public works engineer and his staff consisting of an assistant public works engineer, an office engineer and a designing engineer, together with eight district engineers and their assistants, one in each of the eight districts into which the Province is divided. The organization is shown graphically in the chart on page 15.

Annual estimates of the funds required for anticipated work in each district are prepared by the district engineer and submitted to the public works engineer. After inspection and possible revision they are submitted to the Provincial Legislative Assembly for inclusion in the budget. The completed budget assigns to each district a certain amount, which is apportioned to various works by the district engineer subject to the approval of the public works engineer. The work is carried out under the direction of the district engineer, who is responsible, and accountable for all expenditures. All accounts are vouchered and approved by the district engineer or his assistant and paid by a Government agent. Copies of vouchers are forwarded to the public works engineer for approval, thence to the deputy minister of public works for the same purpose, then to the audit department and finally to the treasury department where the expenditures by the Government agent must be approved. In some of the districts most of the road work is done by day labor, but in general new work is usually undertaken by contract. There is no "statute labor."

Administration in Ontario.—One of the second group of Provinces, in which road control is not entirely in the hands of provincial officials, is Ontario. The units of government sharing in road control in this Province are the Province, the county and the township.

Road construction and repair was originally a local government function. The roads of least importance, generally those of purely township significance, are still, in this Province, maintained by the townships from township rates, and accounted for solely by the township council, with the exception of the salary of the township road overseer, of which 25 per cent up to $150 per year is paid by the Province.

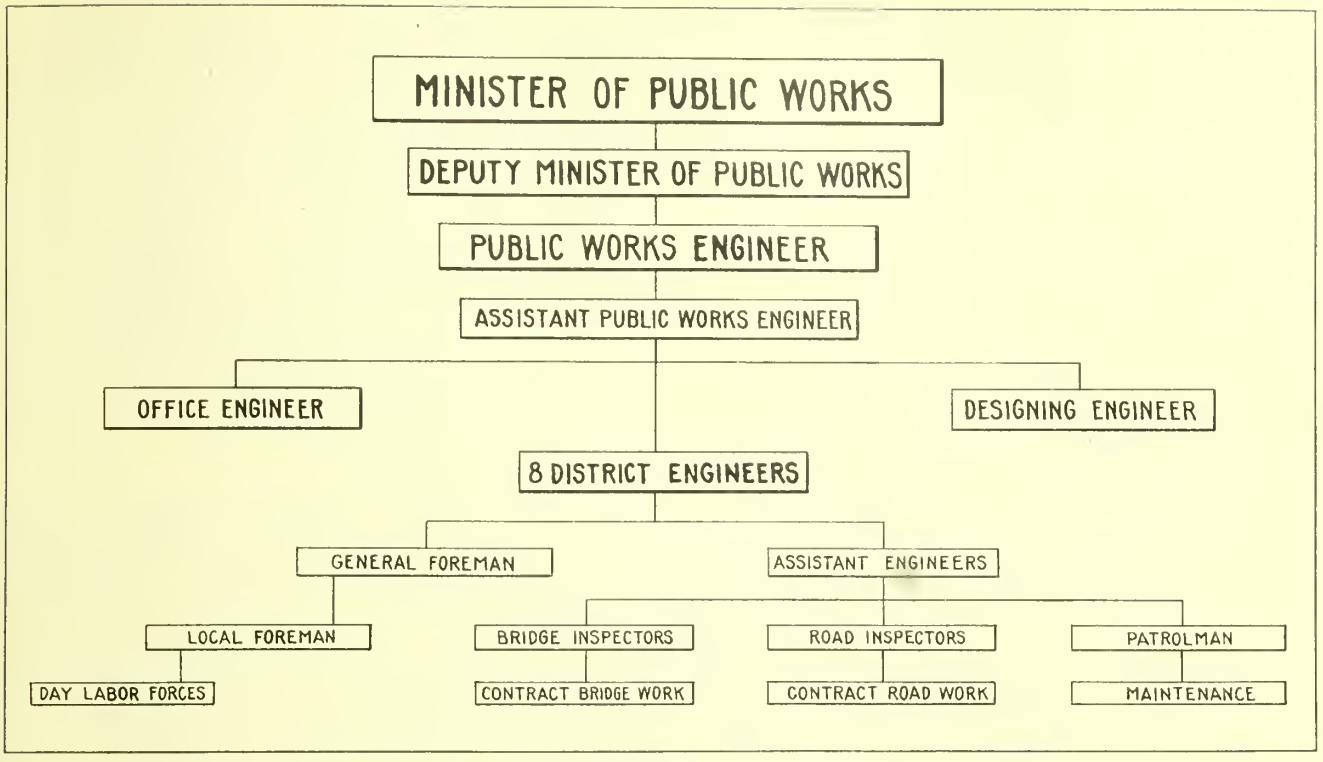
As in this country very little progress was made in road improvement while it was in the hands of local authorities. The first steps toward real progress were made in 1901 when the passage of the highway improvement act provided for the extension of provincial aid to the counties.

County roads.—The condition introduced by this act was very similar to the systems of State aid in the United States. Briefly the act authorizes county councils to assume systems of roads to be known as county roads, which, upon approval by the provincial authority, may receive provincial aid in construction and maintenance. The county system must be adopted by by-law passed by a two-thirds majority of the county council representing at least one-half of the total equalized assessment of the county. When roads are assumed by the county in this manner the township councils cease to have control over them, nor should they make any expenditure on them. The county council is thereafter responsible for construction and maintenance. A county road superintendent, appointed by county by-law and approved by a provincial order in council, is placed in actual charge of road work; but all plans, specifications, and accounts must be approved by the department of public highways before the provincial grant is made. To roads selected and constructed in this manner the Province grants 40 per cent of the expenditure on construction and 20 per cent of the cost of maintenance.

A city may cooperate with the county council in improving the leading county roads adjacent to the city, and thereby obtain a more substantial type of construction for such suburban roads. In such a case the contribution of the Province remains 40 per cent and 20 per cent for construction and maintenance, respectively, but the county and city divide the balance of the cost in each case between them.

Provincial county roads.—Certain county roads of more than local importance, which carry a considerable portion of through traffic, but which are not of sufficient importance to be classed as provincial highways, are classified as provincial county roads. Such roads continue under county control, but because of the through traffic they receive an increased provincial subsidy. In general, they form branches of the "provincial highway system," joining cities and other important terminal points of traffic. To roads of this character the Province grants 60 per cent of the cost of construction and maintenance.

Provincial highways.—In addition to the roads of the classes described above, a system of provincial highways was authorized in 1917, with a view to bringing the construction and maintenance of the principal highways of the Province under the immediate control of the provincial highways department. The department, with the approval of the lieutenant governor in council, is authorized to take over any public highway on behalf of the Crown. The department, thereafter, makes itself responsible for the proper construction and maintenance of the highways assumed. Adjacent to cities the costs of such highways are borne in the proportion of 40 per cent by the Province, 30 per cent by the city, and 30 per cent by the township through which the road passes; outside suburban areas, the Province pays 70 per cent and



BRITISH COLUMBIA HIGHWAY ORGANIZATION.

the township 30 per cent. Provincial control is vested in the department of public highways, with a construction engineer acting under the chief engineer of the department, and resident engineers in charge of the several sections of road, who employ foremen and day labor gangs. For special work contracts may be let on authority of the minister of public highways.

SOURCES OF REVENUE AND EXPENDITURES.

The Dominion.—The $20,000,000 available for Federal aid is derived from the Federal treasury by appropriation made in the Canada highways act passed in July, 1919. Expenditures from this appropriation are to be made over a period of five years and are to take the form of grants to the several Provinces upon condition that they shall expend at least half again as much as the Dominion grant. The allotment of the Dominion funds to the several Provinces made in the manner described elsewhere in this article is substantially as shown in the following table. The minimum amount which the Provinces must contribute in order to receive the Federal money is shown in the third column.

Province.	Federal grant.	Required of Province.
Alberta	$1,477,810	$2,216,715
British Columbia	1,251,955	1,877,932
Manitoba	1,602,265	2,403,397
New Brunswick	1,168,845	1,745,767
Nova Scotia	1,468,720	2,203,080
Ontario	5,877,275	8,815,912
Quebec	4,748,420	7,122,630
Prince Edward Island	603,455	905,182
Saskatchewan	1,806,255	2,709,382

The grants will be made and the work directed by the department of railways and canals. Regulations governing the expenditures have been drawn up by an honorary advisory commission consisting of C. A. Magrath, Ottawa; J. P. Mullarkey, Montreal; and Horne Smith, Toronto.

Up to the present time very little, if any, of the money has been actually expended, but it is expected that the coming year will show very active disbursements as the work already planned gets under way.

The Provinces.—In respect to the methods of raising revenue there is no uniformity among the Provinces of Canada. In this they resemble our own States. Perhaps the nearest approach to a generalization that can be made is that none of them employ that method which is so common in our own system—the taxation of abutting property. Nowhere in Canada is such a tax levied, though in Ontario land adjacent to an improved road is supposed to be assessed 20 per cent higher by virtue of the improvement.

Nor have the automobile revenues been devoted to road construction to any degree corresponding to the practical unanimity among our States. Provincial road revenues are provided by appropriation by the legislature from the consolidated revenue funds, which are made up in part of the motor-vehicle revenues, but apparently the latter are not definitely set aside for road purposes as in this country; and the principle of applying them to road maintenance as distinguished from construction is not recognized.

In British Columbia and Prince Edward Island, two of the group of four Provinces in which road

authority is solely a function of the provincial government, road revenues are collectible only by the Province. In British Columbia there is, in fact, no special levy for road improvement, funds for construction and maintenance being derived by appropriation from the general revenues of the Province. In this Province an act of the legislature in March, 1919, provided for a loan of $3,500,000 for road purposes, of which it is stipulated no more than $1,500,000 is to be expended in any one year.

Prince Edward Island levies a special road poll tax, but derives the larger part of its highway revenues from the taxes on motor vehicles and stock.

In Nova Scotia and New Brunswick, the other two Provinces of this group, taxes for road improvement are levied upon the towns and counties, though they have no control over the expenditure of the money raised. In Nova Scotia, for example, each town is taxed for highway purposes one-tenth of 1 per cent on all property assessed for taxation. Each county pays a tax of not less than 40 cents on each $100 of taxable property, and in addition each male between the ages of 21 and 60 pays a poll tax for highway purposes. Both the towns and the counties turn the amounts received over to the provincial treasurer who in turn remits them to the provincial highways board. The law requires, however, that taxes collected in this manner must be spent in the county in which they are raised. In addition to the money derived from the county and town taxes, the provincial government appropriates annually from the general provincial funds a sum of money which may be expended for road purposes in the Province at large.

In the remaining Provinces funds are raised for highway purposes by the towns and counties as well as by the Provinces, and the moneys collected are expended by the unit of government which collects them.

Ontario's provincial expenditures are made from appropriations from the consolidated revenues of the Province. The appropriations are based on the automobile revenues but are not confined to them. The local revenues are derived from county taxes and bond issues, and from township taxes, which by by-law of the township councils may be commuted into statute labor.

In Manitoba provincial revenues for construction are derived from the sale of debentures. The consolidated revenues and general road tax funds are usable for maintenance only. Local road construction under the control of the municipal councils may be financed in three ways, either from the current revenues of the municipality (town); or from a special tax for road construction, which can be no larger than 5 mills on the assessed valuation; or by the sale of bonds. In case it is decided to resort to a bond issue, the amount to be raised must conform to the engineer's estimate, the issue must be assented to by the taxpayers, and the amount of the issue is limited to 10 per cent of the assessed valuation.

Provincial funds for road purposes in Saskatchewan are in two accounts, known, respectively, as the revenue account and the capital account. The revenue account consists of money derived from the general revenues of the Province and is usable for surveying, construction, and maintenance of roads and for the construction and maintenance of small timber bridges. Funds for the capital account are derived from the sale of bonds, and may be devoted to the construction of permanent roads and bridges of steel or concrete. Local funds in Saskatchewan are obtained by taxation of municipal property.

One of the most interesting methods of financing road improvement is that which obtains in Quebec. The provincial government was authorized in 1912 to borrow $20,000,000 for road purposes. This money is being used to assist the municipalities in two ways. One way is by the extension of a grant covering 50 per cent of the cost of the cooperative roads built, up to a certain amount fixed by the minister of roads. The second and more interesting method permits the municipality to borrow the whole cost of the improvement from the Province, paying for the loan at 3 per cent interest for 41 years, the government contributing the principal. Obviously, the annual cost to the Provincial government under this method of delayed payment is slightly less than 2½ per cent of the initial cost of the improvement, while the municipality pays 3 per cent of the cost each year. It is reported that the plan is working out in a highly satisfactory way. The assistance of the government has stimulated municipal enterprise, and a splendid reform, now well under way, is the result.

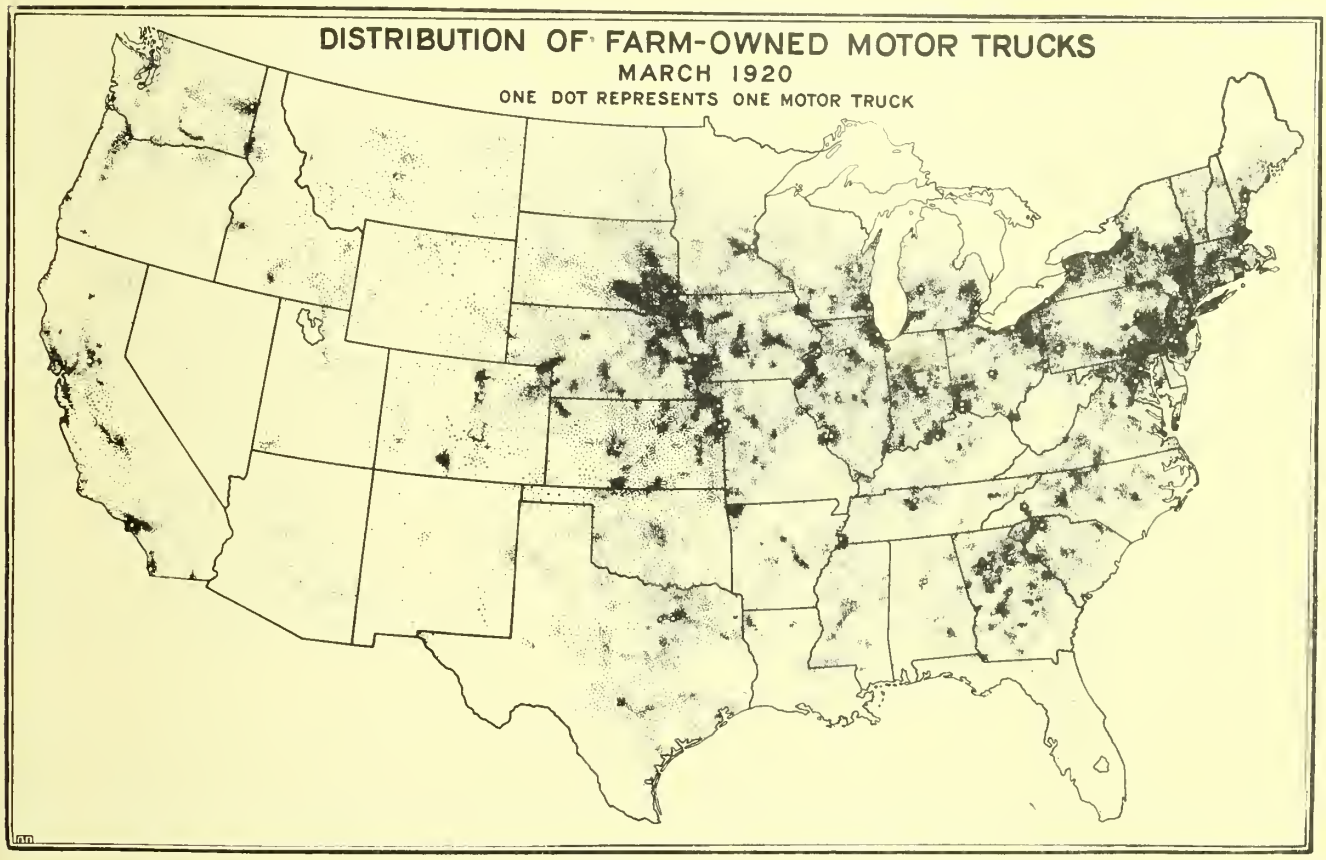
MILEAGE AND CHARACTER OF ROADS.

According to the minister of railways and canals there are approximately 250,000 miles of road in the Dominion of Canada, which is about one-tenth of the mileage in the United States. Reports from the various consuls indicate that the total mileage is slightly in excess of the minister's figure, the reported mileages by Provinces being as shown in the following table:

Province.	Mileage of road.
Alberta	30,000
British Columbia	14,600
Manitoba	68,000
New Brunswick	15,000
Nova Scotia	18,000
Ontario	42,000
Prince Edward Island	3,800
Quebec	40,000
Saskatchewan	30,000
Total	261,400

(Concluded on page 22.)

CHARACTER OF FEDERAL-AID ROADS CONSISTENT WITH TRAFFIC DEMANDS



DISTRIBUTION OF FARM-OWNED MOTOR TRUCKS IN THE UNITED STATES.

THE provision of the Federal-aid road act which requires that the roads constructed with the aid of Federal funds must be "substantial in character" has been construed in its application by the Secretary of Agriculture in accordance with the following principles:

1. That the proposed highway must be an improvement upon the existing highway, and at least as durable as other roads in the section in which it lies;
2. That the type of surfacing must be adequate to serve present and probable future traffic as determined by a traffic census and an estimate of probable development.

Guided by these principles the Secretary has approved roads of all types from the lowly earth road to expensive surfaces of bituminous and cement concrete and brick. No attempt has been made to enforce the construction of the higher types under all circumstances, because it has been realized that the conditions in all cases do not require the great outlay which the construction of such roads entails.

The department and the several State highway departments have often been criticized upon the score of this policy, the critics pointing to the total mileage of roads of low type as proof that the roads constructed under Federal aid are inadequate to serve modern conditions.

Those who have been familiar with the true conditions have been confident that the selection of the lower type surfaces has been justified by the circumstances of each individual project, but in the aggregate, the large mileage of earth, sand-clay, and gravel roads which has been approved has appeared to substantiate the unfavorable criticism of those who have dealt only with total figures.

The roads constructed have been classified as to type of construction, and the situation with regard to the selection of types in the several States and in the United States as a whole has been clearly shown in simple tabular form which could be comprehended at a glance. But no similar means of presenting the related traffic conditions has been available; and it has not been possible, therefore, to demonstrate the

injustice of the criticisms without going into the circumstances of each particular case.

MOTOR TRUCK AND ROAD TYPE CHARTS.

The valuable survey of the distribution of farm-owned motor trucks recently made by the Office of Farm Management of the Department of Agriculture has supplied the desired comparative data in a simple graphical form. The map prepared by the Farm Management experts is reproduced on page 17. On it each dot represents one motor truck, and the density of the shading conveys at a glance the extent of motor truck usage in the various sections of the country.

Obviously the necessity for the construction of such hard-surfaced types of pavement as brick, concrete, and bituminous concrete is a direct function of the number of motor trucks the pavement will be called upon to withstand when it is constructed. Where motor truck traffic is light, the chances are that automobile traffic is also light, and in the absence of these two forms of traffic there is no necessity for a stronger surface than is afforded by such materials as sand-clay, or gravel, or broken stone at best.

It it interesting, therefore, to compare the distribution of motor trucks and the relative density of motor truck traffic in various places, as revealed by this chart, with the character of the surfaces which have been selected for Federal-aid roads in the corresponding places as shown by the other chart on page 19.

The second chart has been prepared by the Bureau of Public Roads to show the mileage of the various types of road under agreement for construction in the several States. The principal types of road have been grouped into three classifications, designated as high, intermediate, and low types respectively. The high-type classification includes brick, cement concrete, bituminous concrete, sheet asphalt, and similar pavements. The intermediate class includes bituminous macadam and surface treated and plain water-bound macadam; and the low-type group is composed of earth, sand-clay, gravel, shell, and similar miscellaneous constructions. The mileage of road of each of the three classes in each State is shown by the length of the sections of the bars in each State hatched to represent the particular types. The approximate mileage of roads of each type can be determined by reference to the scale of miles. In this connection, however, the relative mileages of the three types in each of the States are of greater interest than their numerical equivalents.

ROAD TYPES AND TRAFFIC DEMANDS.

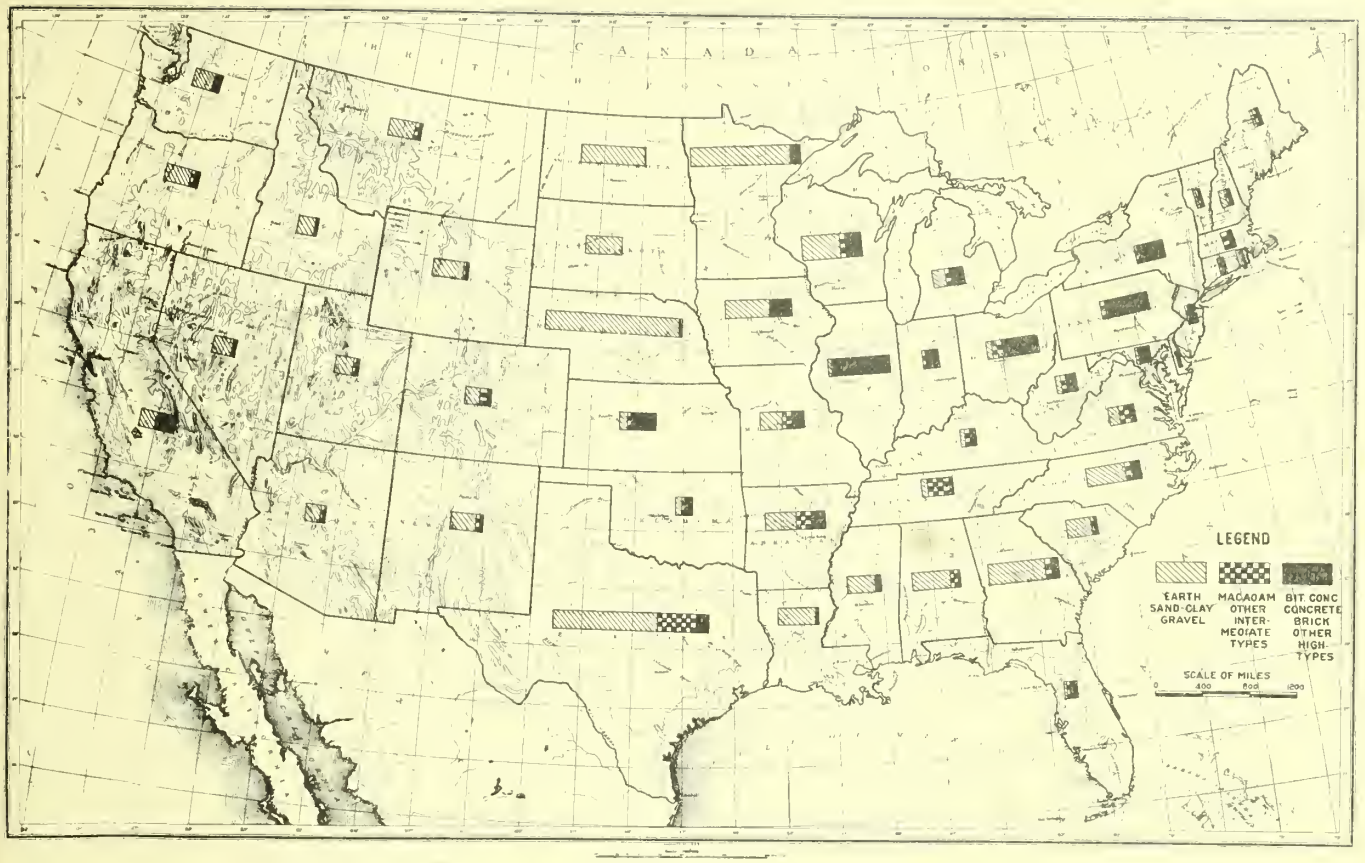
The fact that stands out most clearly by a comparison of the two charts is that the areas of greatest concentration of motor trucks are practically identical with the territory in which Federal-aid roads are predominantly of the higher types. The salient features of the highway map are: The belt of roads of the higher types which extends from the New England and Middle Atlantic States westward north of the Potomac and Ohio Rivers to the Mississippi; the beginnings of a movement toward the acquisition of roads of these classes in the other Atlantic seaboard and Pacific Coast States; and the great preponderance of low-type roads in the Great Plains and Rocky Mountain States.

Turning to the motor-truck chart it is evident at once that the same areas which hold the bulk of high-type Federal-aid roads are those which have the largest numbers of farm-owned motor trucks; and the scarcity of the motor trucks in the Plains and Mountain States offers the most convincing reason possible for the selection of the low-type roads in those sections.

Naturally there are exceptions to the general agreement of the two maps. In the State of Florida, for example, no great concentration of motor trucks appears, yet the high and intermediate types of highway predominate. This condition is explained, of course, by the heavy tourist automobile traffic, the consequent necessity of providing some sort of surfacing for the sand roads, the dearth of local road building material of the cheaper sort, which has resulted in a general resort to brick and concrete throughout the State.

On the contrary, the States of Nebraska, Iowa, and South Dakota do not appear to have as great a mileage of high-type road as the concentration of trucks would indicate to be desirable. The explanation in this case is that these States have a well-defined policy in accordance with which they are expending their funds for the most part to grade and drain the native road bed with the fixed purpose of adding the surfacing material at the earliest possible date. The almost entire absence of roads with any improvement whatever, and the large mileage which required improvement, when these States set out upon their work of highway improvement only three or four years ago, makes this policy an eminently wise one. The money expended for grading and drainage—every dollar of it—goes into a lasting improvement, an improvement which, small though it may be in Eastern eyes, is yet a substantial improvement over previous conditions, and is moreover the ground-work for future surfacing, when the whole territory which must benefit has been lifted out of the deepest mud by adequate drainage and grading.

These are the outstanding exceptions to the general agreement of the two charts. On the other hand, in a State like Ohio, where, according to the motor-truck chart the roads must bear a heavy concentration of trucks, Federal aid has resulted in the construction of types of road which are designed to meet the requirements of truck traffic. Sixty-nine per cent of them



MAP SHOWING TYPES OF FEDERAL-AID ROADS UNDER CONSTRUCTION IN 1920.

are high-type roads, 20 per cent are of intermediate type, and only 11 per cent are included in the low-type classifications. This represents not only a strong effort to provide roads suitable for the loads, but is, in every respect, an advance from the conditions which existed in the State just before the passage of the Federal-aid act, when 81.8 per cent of all the roads of the State were of low types, 16.6 per cent were intermediate type, and only 1.6 per cent could be classified as high type.

It is recognized, of course, that the number of rural-owned motor trucks is only a portion of all the trucks owned in the United States. But the great majority of city-owned trucks are operated in the States which show the greatest preponderances of high-type roads, and those that are owned in other sections, it is safe to say, impose no demands upon the highways of those sections beyond a radius of 60 miles from their city homes. And as it happens that these are sections where the distances between cities are great, the bearing of the city trucks upon the highway problems of the States as a whole is not great.

In the main these charts present a complete and very convincing answer to the criticisms that have been directed against the types of highway approved for Federal-aid projects.

IMPROVING IMPROVED MARYLAND ROADS.

(Continued from page 8.)

which deteriorate from freezing. Regardless of how well these emulsions are adapted to summer and fall patching they are not used, because the possibility of not having material when it is needed in the spring more than offsets any advantage they possess at other seasons.

In conclusion, the writer believes that Maryland's policy which makes it necessary from time to time to improve her improved roads is fundamentally sound and correct. Under it she has become one of the "best roaded" States of the Union. The improvements which keep her moderate-priced roads continually up to date cost far less than the high type roads which elsewhere are being built to carry traffic no heavier than her roads carry. The Maryland plan starts with a relatively small investment in admittedly low-type road. By a process of gradual improvement, by selective treatment of the weak places, it builds up a better road from year to year, always conserving the bulk of the previous investment. It is a plan which is more like the French plan than is to be found anywhere else in the United States. It differs sharply from the method which attempts by expenditure of vast sums to build at once, forever.

Marylanders often wonder whether the public which elsewhere pays the huge cost of the so-called high-type roads fully understands that the best pavements built to-day are not going to give the service implied by the catch word "permanent." We wonder whether there exists in the public mind that wholesome doubt of the "permanence" of such roads which in Maryland makes "maintenance" a bigger word than "construction." Certainly, if this be not the case, if sufficient funds are not provided for maintenance, and for reconstruction, when necessary, this country is due for a tremendous set-back in road construction.

HIGHWAYS IN THE HIGH SCHOOLS.

By C. J. TILDEN, Professer of Engineering Mechanics, Yale University.

SCHOOLS make citizens. Whatever has to do with community life and development is a proper subject for study, if it can be fitted to the intellectual status of the child. Our highway systems—State, county, and municipal—have recently become so important throughout the country that the future citizen may well be required to learn something about them. Within the past year or two the annual appropriation of public moneys for highway construction and maintenance has increased fivefold. Pleasure cars are multiplying with astonishing rapidity, and motor transport is becoming an industrial necessity in many communities. Not only must new roads be built, but old roads must be rebuilt to meet the increasing demands of traffic. This, of course, spells more money and the need for more wide-spread efficiency and wisdom in spending it.

In attempting to put some sort of instruction in highway matters into schools of high and grammar grades, it is not necessary to think in terms of a text-book or set courses of study. Training the powers of observation and of expression is one of the chief objects of education. Let the student look at something, with more or less guidance as to what he is to look for, then tell or write about what he sees, and he has gained both in knowledge and intellectual power. Hence the many exercises in "composition," "essays" or "themes," on topics which may either be assigned by the teacher or chosen by the student.

OUTLINE FOR STUDY OF HIGHWAYS.

In the following outline, which has the highway as a basis, a series of such topics is suggested, planned to stimulate observation and provoke interested and fruitful discussion. One advantage in the general subject of highways is that the study and observation can begin at home. Both economic and construction problems have been solved (or else are more or less obviously still to be solved) in building the road, street, or boulevard that runs past the schoolhouse. The study of these questions—finding the answers—can not only be made of interest to the schoolboy, but will lead by a logical path, albeit with many ramifications, to the bigger problems of county, State, and national systems of transportation and communication. Most of the topics in the following outline have been put in the form of questions. Some of these may be answered by direct observation, others (as, for example, those of an economic nature) require further investigation, study of maps, town or county records, collateral reading, etc.

THE ROAD BY THE SCHOOLHOUSE.

Where does it come from?
Where does it go?
What is "the right of way"?
  To whom does it belong?
  How was it acquired?
  The fences or walls—what is their purpose?
The road itself, that is, the traveled way.
  How was it made?
  What material was used?
  How is it maintained?
  What pays for it?
  Who has charge of it?
  The alignment, or changes in direction; curves and turns.
  The grade, or differences in elevation.
  Side ditches and drainage.
The nearest crossroads in each direction.
  Where do they lead?
  Which is the "main" road?
  Of what general system—city, county, or State—are these roads a part?
How could you measure the usefulness and importance of these roads? (Approximate number of vehicles per hour, or per day, or per season; beauty of scenery; historic associations; transfer or delivery to or from markets of farm produce, coal, provisions, manufactures, etc.)

Other topics will readily suggest themselves and various rearrangements and combinations may be made. The list above, as will be seen, is designed to stimulate interest in the highways right at home, but the boy or girl who has carefully considered such questions and thoughtfully answered them from personal observation and study is in better shape to deal intelligently with similar questions of much wider scope.

For older students these topics may be extended and broadened considerably. Valuable lessons in geography may be learned in connection with the "how" and "why" of road building. There is no reason why certain elementary phases of highway engineering, particularly those which lend themselves readily to observation in the field, should not be studied with profit and interest by high-school students. By no means the least of the many advantages of such study would be the stimulation of interest in highway engineering, or transport engineering, as a life work. There can be no question that the opportunities in these fields during the next decade or two will be unusually attractive.

USING CONTOUR MAPS.

The ability to read contour maps intelligently is an accomplishment of considerable value, and adds greatly to the interest and enjoyment of motoring, hiking, or any other kind of outdoor activity. It may be acquired by any intelligent boy or girl of 12 to 14. The topographic atlas sheets of the United States Geological Survey are particularly useful in studying actual conditions of highway location—lines, grades, economic and industrial relations, etc.—and most of

the important areas of the United States have been mapped. The sheets may be had at a nominal cost. Many individual exercises on these maps—such as the grade or profile of a given road, why it does not run in a straight line, its relation to railways, streams, and other roads, the visibility of natural objects from various points on it, etc.—are quite within the interested grasp of high-school students.

Among the exercises which may be followed out on these maps, and, where conditions permit, extended to observation in the field, are those relating to the way roads are laid out. Some of the older highways of New England appear on the map as straight lines between towns, the line following for miles over hills and through valleys without regard for such obstacles. By far the more usual way is to follow approximately along the contour lines, going around hills instead of over them, thereby avoiding undesirable hills. In many places in the Middle West where public-land surveys have been made the public roads follow the north-south and east-west section lines. Then there are roads that "just growed," like Topsy, or developed from buffalo tracks or cow paths. A comparative study, on the topographic map sheets, of roads in flat country and roads in hilly country will bring out most interesting and instructive differences. The relation of roads and contour lines is strikingly shown on the maps of the big mountains, such as Mount Ranier, Pike's Peak, Mount Washington, and others. For more mature students some elementary studies of the economic significance of grades on streets in the vicinity of the school could well be made.

LEARNING FROM ROAD CONSTRUCTION.

Where road construction is in progress a great deal of useful information may be gathered. The way in which the roadbed or "subgrade" is prepared, the desirability of balancing cuts and fills, the material used to make the road surface and where it comes from—what part if any has to be brought from a distance and what is obtained locally—may all be noted from observation supplemented by a few questions. In general, the engineers and superintendents on such work will welcome intelligent questioning and gladly give all the information they can.

The whole question of crossing steams and rivers, road drainage, etc., offers many topics for observation and study. Taking care of water that would otherwise destroy the road is a problem that every road builder has to face. To the boy or girl with a creative imagination—and most children have this quality until it is educated out of them—bridges and culverts are delightful and fascinating structures. The impression on one small child is charmingly given in The Story of Opal.[1] "Long time ago, this road did have a longing to go across the rivière. Some wise people did have understandings and they did build it a bridge to go across on. It went across the bridge and it goes on and on between the hills."

A knowledge of some of the simple terms in bridge nomenclature—a beginning of the "anatomy" of bridges—would stimulate the interest and greatly quicken the power of observation. The various ways of classifying bridges, as "through" or "deck" spans; or on the basis of the material used—stone, concrete, steel, timber, combination; or with respect to the structural form—beam or girder, truss, cantilever, arch, suspension, or pontoon—may be readily learned by children of high-school age. Even the principal steps in bridge building may be studied and written about by a bright youngster, if there is some work of the sort on in the neighborhood.

SAFETY WILL FURNISH TOPICS.

The many requirements for safety will furnish a variety of topics for school children's essays and oral discussions. The dangers of railroad crossings at grade and the economic justification for abolishing them, the importance of an unobstructed view up and down the track as a vehicle approaches, the disadvantages of sharp turns, etc., are suggestive subjects. Similarly there might also be mentioned the questions raised by street intersections and turns. In every town there are many crossings where the autoist's view is unnecessarily limited by fences, shrubbery, or buildings, or where sharp curves with limited visibility invite serious accidents. Guideposts, markers, and other signs for the most efficient guidance of traffic through thickly-settled communities are also a part of the bigger and more inclusive topic of the economic importance of safety and guidance—the actual money value of human life and of accident prevention.

Another question, in solving which the engineer and economist will need the help of enlightened public opinion (and this enlightenment should start in the public schools), is that of the relation of the public highways to railroads and canals. The advantage of long hauls by rail and short hauls by motor trucks, feeding into main terminal points by radiating systems of highways, a division of the transportation burden by parallel systems of water, rail, and road transportation, are some of the subdivisions of this general heading.

This listing of topics is not intended to be complete or exact, but merely suggestive. Those that refer to construction could best be utilized when construction work happened to be in progress in the vicinity of the school. Many of the other topics may be studied from maps, of which the students might be required to make tracings or free-hand sketches showing the particular features which it is desired to emphasize, or

[1] Atlantic Monthly, March, 1920.

about which the exercise is being written. State highway departments often feel the need of a better popular understanding of the problems of road construction, and their officials would doubtless cooperate in a hearty manner. Looking ahead, it is easy to see an actual shortage of men qualified to carry on the work of highway development, so rapid is the growth of the good-road movement. Highway instruction in high schools offers opportunity to State highway departments to develop a body of future citizens equipped with a better understanding of the need for roads and the problems likely to be met in building them, and, at the same time, to stimulate interest in the profession of highway engineering.

ASSISTANCE BY HIGHWAY DEPARTMENTS.

State departments and county engineers can help teachers (1) by assigning members of their staffs to deliver occasional lectures, simple in text and preferably illustrated with lantern slides; (2) by furnishing photographs of highways and construction work for classroom or reference use; (3) by assisting teachers in the explanation of work in progress which can be inspected by classes of students. Many States also issue bulletins or reports which are valuable for reference.

The Federal Bureau of Public Roads has a large amount of material which is available for assisting in school work of this kind. In addition to bulletins, circulars, and other printed matter which will be sent free to teachers and others who are interested, lantern slides and motion-picture films may be loaned, without charge, to schools equipped to make use of them. Other material, of a graphical or pictorial nature, will be developed from time to time and will be available for use in connection with public-school instruction.

But the best equipment for such high-school work as this is a live, wide-awake community which believes in building good roads and keeping them in good shape. Under such conditions there will never be any lack of material for making interesting studies of the economic, social, and constructional problems of highway communication. A collection of maps, some good photographs, and a carefully-chosen list of books and magazines would complete a useful educational outfit. The assumption must, of course, be made that these facilities are at the command of an interested, active-minded, and inspiring teacher.

HIGHWAY ADMINISTRATION AND ROAD CONDITIONS IN CANADA.

(Continued from page 16.)

About 30,000 miles of the entire system are surfaced with some material, varying from sand-clay to concrete and bituminous concrete, but only about 10,000 miles are included in what may be called roads of the first class—that is, heavily traveled main thoroughfares.

Roads surfaced with concrete and bituminous materials are confined almost entirely to the eastern Provinces of Nova Scotia, Quebec, and Ontario. Prince Edward Island and Alberta have no surfaced roads at all. British Columbia, Manitoba, Saskatchewan, and New Brunswick have very little surfaced mileage, and such as they have is almost entirely gravel or sand-clay. These Provinces constitute a sparsely settled region in which the traffic has not yet become heavy enough to warrant the surfacing of roads. There are thousands of miles of trails in these Provinces, however, which are not included in the mileage of roads reported.

Methods and standards of construction for the various types of roads are practically identical with those prevailing in the United States, as are the costs of construction and maintenance.

TRAFFIC AND ROAD CONDITIONS.

In 1918 there were in the entire Dominion of Canada approximately 262,000 motor vehicles. The numbers of motor trucks, automobiles, and motor cycles were not reported separately, and no estimate of the numbers of each in the Dominion can be given.

However, nearly one-half of the total number were registered in Ontario, in which the number of the several classes of vehicles were passenger automobiles, 101,599; motor trucks, 7,529; and motor cycles, 5,002. In 1917, the year previous, it was found that approximately 25 per cent of all motor vehicles registered were in the hands of farmers. The same year it was reported that there was one car for each 39 of the population in Ontario and one for each 12 persons in Saskatchewan. These figures compare very closely with the figures expressing the same relation for the same year in the States of New York and Montana, which border upon the two Canadian Provinces. New York had one car for each 30 persons and Montana 11, according to data compiled by the Bureau of Public Roads.

The Ontario reports for 1917 show that nearly 75 per cent of all motor trucks registered were classed as having a capacity of 1 ton or less, over 97 per cent were 3½ tons or less, and less than 3 per cent were of 4 tons' capacity and upward. In 1918 there were in the Province only 18 trucks capable of carrying 6 tons or more of load.

Except in Ontario and Quebec, and in parts of British Columbia motor traffic has not yet grown to proportions which justify extensive construction of the higher types of roads. Conditions in these Provinces or, at any rate, in parts of them are very similar to the traffic conditions in the border States of the United States. Parts of them are still in an undeveloped state, and very large parts of the other Provinces are still very sparsely settled. In the whole Province of Prince Edward Island in 1918 there were only 35 motor trucks. Still this country is developing with great rapidity, and Canadian road builders are attempting to make their work safe for the foreseen future. In this they are fortunate in having as a guide the experience of the United States, which has recently trod the same path.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN AUGUST, 1920.

State.	Project No.	County	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	79	Dallas	3.144	Gravel	Aug. 4	$39,374.54	$19,687.27
Arkansas	78	Lincoln	9.980	....do	Aug. 12	21,039.48	10,500.00
	112	St. Francis	4.180	....do	Aug. 13	40,956.30	10,000.00
	82	Little River	6.570	....do	Aug. 14	55,775.77	20,000.00
Colorado	40	Yuma	3.504	....do	Aug. 3	29,767.69	14,883.84
	120	Jefferson	1.491	Concrete	Aug. 28	59,621.48	29,810.74
Georgia	180	Gwinnett	2.300	Sand-clay	Aug. 3	38,338.14	19,169.07
	181	De Kalb	1.913	Hard surface	Aug. 13	77,000.93	5,000.00
	186	Johnson	3.100	Gravel	Aug. 28	27,665.44	13,832.72
	178	Murray	6.500	Topsoil	Aug. 31	43,749.20	21,874.60
Idaho	47	Kootenai	8.250	Gravel	Aug. 17	20,000.00	10,000.00
Illinois	13	Sangamon	9.710	Various hard types	Aug. 3	222,480.50	55,620.12
	14	Fayette, Marion, Washington, Perry, Jackson, Union, Alexander.	54.000	Earth	Aug. 11	1,400,568.30	350,142.07
Iowa	45	Mitchell		Gravel	Aug. 21		[1] 40,000.00
	52	Audubon		Earth	...do		[1] 60,000.00
	57	Cedar		....do	...do		[1] 30,000.00
	64	Jasper		....do	...do		[1] 50,000.00
	70	Mahaska		....do	...do		[1] 60,000.00
	74	Clayton		....do	...do		[1] 70,000.00
	75	Marion		....do	...do		[1] 50,000.00
	76	Chickasaw		Gravel	...do		[1] 30,000.00
	81	Taylor		Earth	...do		[1] 60,000.00
	83	Union		....do	...do		[1] 80,000.00
	86	Jones		....do	...do		[1] 40,000.00
	90	Iowa		....do	...do		[1] 50,000.00
	98	Winneshiek		....do	...do		[1] 60,000.00
	103	Delaware		Gravel	...do		[1] 40,000.00
Kansas	66	Crawford	11.500	Earth	Aug. 13	239,674.02	57,500.00
Louisiana	78	St. Martin	5.600	Gravel	...do	73,641.73	36,820.86
Missouri	98	Hickory	7.000	....do	Aug. 11	39,002.48	19,501.24
	104	Webster	8.500	....do	...do	30,200.00	15,100.00
	141	Montgomery	6.000	Macadam	Aug. 12	53,694.36	26,847.18
	146	McDonald	7.750	Gravel	...do	27,900.00	13,950.00
	152	.....do	3.680	....do	...do	13,260.50	6,630.25
	148	Phelps	20.000	....do	Aug. 13	82,736.00	41,368.00
	156	Polk	8.300	....do	...do	40,743.23	20,371.61
	139	Pulaski	18.670	....do	...do	84,297.93	42,148.96
	149	Green	7.000	Earth	...do	34,999.99	17,499.99
	153	Christian	9.000	Gravel	...do	17,568.00	8,784.00
	154	Barry	5.500	....do	...do	21,500.00	10,750.00
	158	Christian	6.500	....do	...do	16,978.00	8,489.00
	135	McDonald	7.000	Earth	Aug. 12	34,799.60	17,399.80
	137	Marion	6.500	Gravel	Aug. 31	55,374.00	27,687.00
	160	Washington	8.240	Earth	...do	43,093.03	21,546.51
Montana	127	Sweet Grass	7.617	Earth and gravel	Aug. 9	37,885.65	18,942.82
	111	Stillwater	0.510	Concrete	Aug. 11	20,483.33	10,200.00
	117	Sweet Grass	6.300	Gravel	Aug. 28	69,215.73	34,607.86
	134	Yellowstone	3.230	....do	...do	26,143.67	13,071.83
	137	Lincoln	4.000	Earth	Aug. 30	19,965.00	9,982.50
New Hampshire	127	Sullivan	1.040	Bituminous macadam	Aug. 12	40,000.00	20,000.00
	128	Merrimack	0.660	Gravel	Aug. 30	18,000.00	9,000.00
	130	Grafton	0.460	....do	Aug. 31	8,000.00	4,000.00
North Carolina	125	Alleghany	13.550	Macadam	Aug. 11	195,125.70	97,562.85
Ohio	127	Montgomery	5.130	Concrete or bituminous macadam	...do	220,000.00	61,000.00
	142	Summit	4.980	Concrete	...do	285,016.60	75,000.00
	164	Richland	3.144	Concrete, bituminous macadam or brick.	...do	153,000.00	33,000.00
	167	Vinton	2.980	Earth	...do	67,000.00	27,000.00
	169	Holmes	2.180	Monolithic brick	...do	82,000.00	25,000.00
	170	.....do	1.987	Concrete or monolithic brick	...do	63,000.00	20,000.00
	159	Wood	3.370	Macadam	Aug. 12	114,400.00	20,000.00
Oklahoma	30	Novata	5.000	Gravel	Aug. 28	[2] 41,800.00	[2] 20,900.00
South Carolina	98	Greenville	2.159	Concrete or asphaltic concrete	Aug. 4	103,750.53	43,180.00
	66	Richland	15.155	Concrete	...do	691,535.51	85,497.05
	100	Union	3.728	Topsoil	Aug. 11	39,077.56	13,828.38
South Dakota	64	.....do	7.000	Gravel	...do	69,388.00	34,694.00
	65	Yankton	13.110	Earth	...do	54,923.00	27,461.50
	66	Union	10.930	Gravel	Aug. 28	102,725.70	51,362.85
Texas	199	Stephens	31.800	Bituminous concrete	Aug. 4	1,251,645.29	200,000.00
	198	Nacogdoches	23.170	Gravel	...do	288,143.90	100,212.35
	197	Smith	2,450	Gravel-clay	...do	45,115.85	22,357.91
	191	Milan	14.557	Gravel	Aug. 12	107,544.14	32,685.48
	194	Coleman	18.400	....do	Aug. 13	263,832.80	90,000.00
	196	.....do	22.500	....do	...do	320,426.72	100,000.00
	201	Nacogdoches	32.680	....do	Aug. 30	364,291.40	141,344.04
	202	Bowie	16.354	....do	Aug. 28	181,844.33	90,000.00
	200	Travis	4.000	Bituminous surface	Aug. 30	57,398.00	28,699.00
Virginia	108	Henrico	3.280	Macadam	Aug. 12	69,079.45	34,539.72
	69	Augusta	3.000	Waterbound macadam	Aug. 30	69,850.00	34,925.00
	32	Fairfax	1.730	Macadam	Aug. 11	[3] 94,799.59	[3] 47,399.80
	41	Alleghany	9.500	....do	Aug. 24	[2] 164,609.50	[2] 82,304.76
	38	Accomac	2.590	....do	Aug. 14	[2] 36,080.00	[2] 18,040.00
Washington	71	Columbia and Garfield	8.620	Crushed rock	Aug. 3	38,940.00	19,470.00
	72	Grays Harbor	1.710	Concrete	...do	71,956.83	34,200.00
West Virginia	100	Tucker	1.900	....do	...do	76,128.80	24,040.00
	101	Randolph	4.410	Earth	Aug. 11	68,000.00	32,320.00
	102	Boone	3.080	....do	Aug. 12	65,500.00	30,080.00
Wisconsin	177	Sauk	3.660	Gravel	Aug. 13	40,683.86	15,000.00
	124	Polk	2.190	Earth	Aug. 12	41,203.64	15,000.00
	178	Ashland	5.980	....do	Aug. 14	41,033.96	14,000.00
Wyoming	92	Natrona	10.795	Selected material	Aug. 12	149,600.00	74,800.00
	96	Goshen	3.250	....do	Aug. 13	28,413.00	14,206.50

[1] Revised statement. Figures given are decreases from those in the original statement.
[2] Withdrawn.
[3] Revised statement. Figures given are increases from those in the original statement.

PROJECT AGREEMENTS EXECUTED IN AUGUST, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	46	Jackson	6.000	Waterbound macadam	Aug. 2	$53,360.47	$26,680.23
	51	Russell	5.440	Sand-clay	Aug. 31	32,185.04	16,092.52
Georgia	65	Dade	2.335	Chert	Aug. 18	65,791.55	32,895.77
	78	Pulaski		Bridge	...do	246,121.42	123,060.71
	80	Glynn	4.200	Concrete	...do	167,318.84	83,659.42
	83	Walton	5.830	Topsoil	...do	40,655.46	20,327.73
	85	Haralson	5.000	Sand-clay	...do	39,820.19	19,910.09
	86	...do	4.860	Topsoil	...do	54,515.08	27,257.54
	109	Dawson	7.505	Gravel	...do	105,900.90	52,950.45
	112A	Laurens		Bridge	...do	73,049.81	36,524.90
	113	Pulaski		...do	...do	121,974.30	30,000.00
	116	Walton	6.997	Topsoil	...do	58,342.58	29,171.29
	117	Gwinnett	8.049	...do	...do	61,081.37	25,000.00
	123	Grady		Bridge	...do	36,158.07	18,079.03
	60	Stephens		Topsoil	...do	[1] 11,435.76	[1] 5,717.88
	23	Forsyth		Topsoil	...do		[2] 6,861.72
	64	Glynn		Hard surface	...do	[1] 6,321.20	[1] 3,160.60
	20	Carroll		Topsoil	...do	[2] 60,454.30	[2] 3,579.47
	11	Lowndes		Bridge (concrete)	...do	[1] 12,785.60	[1] 6,392.80
	16	Meriwether		Sand-clay	...do	[1] 12,761.92	[1] 6,380.96
	125A	Lee	5.681	...do	...do	40,000.00	20,000.00
	139	Taliaferro	5.530	...do	...do	31,335.39	12,000.00
	144	Macon	3.785	...do	...do	9,975.84	4,987.92
	147	Troup	13.240	Topsoil	...do	121,578.42	50,000.00
	89	Baker and Mitchell		Bridge	Aug. 31	94,600.00	47,300.00
	55A	Walker	19.865	Waterbound macadam	...do	195,411.31	90,000.00
Louisiana	17	Tangipahoa	4.910	Gravel	Aug. 23	65,541.08	32,770.54
	41	Jefferson	2.940	Shell	...do	30,053.21	15,026.60
	52	Rapides	13.300	Gravel	...do	163,803.58	81,901.79
	53	Madison	10.490	...do	...do	133,522.67	66,761.33
	56	La Salle	12.980	...do	Aug. 24	111,820.83	55,910.41
	62	Beauregard	34.980	...do	Aug. 23	435,997.60	200,000.00
	54	St. Bernard	3.220	Tarvia macadam	Aug. 24	73,282.22	36,641.11
	14	Caldwell	3.720	Sand-clay and gravel	Aug. 23	[2] 92,181.10	[2] 42,000.00
	45	Caddo		Gravel	...do	[2] 18,702.81	[2] 9,351.41
Minnesota	97	Olmstead	14.540	Earth	Aug. 31	175,765.86	87,882.93
	114	Sherburne	7.320	Concrete	...do	285,039.40	142,519.70
	98	Todd	15.700	Gravel	Aug. 18	100,107.09	50,000.00
	103	Renville	14.560	...do	...do	117,887.80	50,000.00
	110	Redwood	10.810	...do	...do	45,962.40	19,000.00
	120	Aitkin	8.060	...do	...do	63,880.22	20,000.00
	63	Stevens	10.008	Concrete	Aug. 19	347,985.48	173,992.74
	89	Le Sueur	7.445	Earth	...do	101,854.31	50,927.15
	92	Anoka	22.500	Gravel and concrete	...do	346,300.28	161,548.91
	107AB	Watonwan	13.969	Concrete or brick or asphalt	...do	582,941.55	200,000.00
	163	Rock	6.010	Gravel	...do	76,935.88	25,000.00
	164	Traverse	15.400	...do	...do	126,919.39	40,000.00
	125	Wabasha	1.510	...do	...do	75,767.07	30,200.00
	40ABC	Meeker	12.256	...do	...do	104,017.65	50,000.00
	159	Ottertail	9.720	...do	...do	79,518.16	39,000.00
	121	Freeborn	9.850	...do	Aug. 31	100,603.91	25,000.00
	135	Beltrami	2.960	...do	...do	20,884.47	10,000.00
	137	Fillmore	6.250	...do	...do	34,296.24	17,148.12
	21	Wabasha		Earth	Aug. 19		[1] 4,800.00
	139	Lyon	8.110	Gravel	Aug. 31	111,046.90	50,000.00
	19	Goodhue	1.480	Gravel and concrete	...do	[2] 131,504.56	[2] 71,769.46
Mississippi	41A	Wilkinson	7.500	Gravel	Aug. 2	89,617.40	44,808.70
Nebraska	33	Knox	11.410	Gravel and sand-clay	Aug. 5	92,382.11	46,191.05
	113A	...do	6.740	Earth	...do	95,171.49	47,585.74
	128A	Seward	7.180	...do	...do	65,795.78	32,897.89
	134AB	...do	18.115	...do	...do	98,303.74	49,151.87
	136A	Pierce	2.110	Sand-clay	...do	33,075.90	16,537.95
	139A	Madison	3.224	Gravel	...do	24,926.08	12,463.04
	43	Johnson	13.857	Earth	Aug. 31	86,286.72	43,143.36
North Carolina	84A	Burke and MacDowell	8.371	...do	Aug. 3	128,193.76	64,096.88
	71	Durham	6.670	Rock asphalt on stone base	Aug. 2	290,329.43	142,570.64
	114	Rowan	2.543	Concrete	...do	107,293.17	50,860.00
	69	Transylvania	9.384	Topsoil	Aug. 3	144,599.13	72,299.56
Washington	40	Walla Walla	3.788	Concrete	Aug. 20	148,821.09	74,410.54
	50	Spokane	4.110	...do	Aug. 3	145,087.23	72,000.00
West Virginia	92	Brooke	.960	...do	Aug. 12	24,324.30	10,240.00
	62	Hardy	6.700	Gravel	...do	57,036.00	28,518.00
	71A	Tucker	2.500	Earth	...do	57,150.00	28,575.00
Wyoming	31	Natrona	1.225	Warrenite, concrete base	...do	161,433.91	73,412.17
	44	Carbon	12.214	Selected material	Aug. 4	62,602.87	31,301.43
	49	Sweetwater	43.921	...do	...do	165,388.08	82,694.04
	63	Park	6.084	...do	...do	52,408.43	26,204.21
	59A	Carbon	9.205	Earth	...do	42,107.84	21,053.92
	62	Sweetwater	16.189	Selected material	...do	57,288.52	28,644.26
	73	Laramie	9.476	...do	...do	73,479.14	36,739.57
	67	Johnson	7.360	...do	...do	66,205.52	33,102.76

[1] Modified agreements. Amounts given are increases over those in the original agreements. Second revision.
[2] Modified agreements. Amounts given are increases over those in the original agreements. First revision.

CORRECTION.

It has been called to our attention that a statement in the article on Asphalt Filler in Granite Block Work, which appeared on page 14 of Volume 3, No. 26, of Public Roads, is misleading. The incorrect statement is as follows: "Granite block with asphalt filler was the type selected by the street department to conform with the rest of Battery Place." The facts are that the rest of Battery Place is paved with granite block, but the filler used is pitch instead of asphalt.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
249. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States, 1914. A summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
463. Earth, Sand-Clay, and Gravel Roads.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests.
555 Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
691. Typical Specifications for Bituminous Road Materials.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and Classification of Rocks for Road Building, Including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. 89. Progress Report of Experiments with Dust Preventatives, 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
77. Experimental Roads in the Vicinity of Washington, D. C.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States. 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States. 1918.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 5, D-12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

RURAL REFERENCE DEPARTMENT
CLEMSON COLLEGE LIBRARY

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 30 WASHINGTON, D. C. OCTOBER, 1920

REMOVING SNOW FROM A BRICK ROAD IN OHIO

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1920

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Eastern States Plan Their Snow-Removal Work for Coming Winter . . 3
J. L. Harrison.

Laying Out Circular Curves by Deflections from the P. I. 13
T. F. Hickerson.

Belgian Traffic Census Report Issued After Long Delay by War . . . 19

A New Concrete Road Film 20

Concrete Road Slabs Undamaged by Washout of Sandy Subgrade . . 21

9,630 Miles of Marked Trails to be Built with Federal Aid 22

The Effect of Alkali Upon Concrete 23
S. H. McCrory.

American Association of State Highway Officials Meet in Washington . . 25

Outline of the Field to be Covered by Highway Research 26
A. N. Johnson.

Modified TNT as a Blasting Explosive 27
Charles E. Monroe and Spencer P. Powell.

Federal-Aid Allowances 29

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT

15 CENTS PER COPY

SUBSCRIPTION PRICE, $1.50 PER YEAR

EASTERN STATES PLAN THEIR SNOW REMOVAL WORK FOR COMING WINTER

By J. L. HARRISON, Senior Highway Engineer, Bureau of Public Roads.

A CLOSE-UP OF THE SNOW PLOW IN ACTION.

MODERN production is not, generally speaking, a seasonal matter. Coal is mined, clothing is manufactured, food is made ready for consumption alike in summer and in winter. The coming of winter stops only the supply of raw products of the soil. Many, even of these produets, continue to pass through the multitudinous proeesses whieh eonvert raw food into forms fit for eonsumption all through the winter.

Transportation, the servant of production, must be ready at all times to serve its master. Stoppage of transportation is equivalent to cessation of production. These faets are axiomatic—platitudinous. We all agree as to their verity.

Railroads do not abandon their shippers when snowdrifts cover their traeks. They clear away the snow. No matter what the cost, trains must be moved. Nor is this done because of any inmediate profit to the railroads, for, as a matter of faet, it might often be eheaper for the roads to suspend traffic for days or even weeks at a time than to go to the enormous expense of clearing the tracks and moving trains when the snow piles high. Rather is this action based on the faet that business conditions and the number of laborers who ean be kept employed are so vitally affected by even minor delays in the distribution of commodities that the railroad administrators realize that the ultimate gain that accrues is worth whatever it costs.

And so it is now eoming to be with the traffie on our highways. The commerce of our eountry as a whole is inereasingly dependent on them. Produetion has increased faster than the eapacity of the railroads to supply transportation. True the eongestion we have experieneed these last few years is abnormal. Nevertheless, the railroads are not anxious to take up again the whole burden of the eountry's transport. Neither is it wise that they should be permitted to if they would. The motor truck will claim its own. Perhaps that means the short haul, but how short or how long none now ean say. At any rate the motor truck has transformed highway freight traffic. Never again

will the highway serve only the locality—the truck reaches out. Fifty miles are as 10 in the day of the horse. And such is the nature of the truck that it brooks no delay. Time saving is its raison d'être. Commodities are moved by truck because they must be moved promptly. Hence the old attitude toward highway traffic has changed. It is no longer of a kind that can be carried on at convenience—halted with indifference.

SEASONAL TONNAGE ON HIGHWAYS.

A few figures will illustrate the point. They are given in the table below and they represent the seasonal tonnage carried over a section near Rahway, N. J., of the principal highway between Philadelphia and New York. The daily tonnage carried in motor trucks (60 per cent assumed to be goods in transit) is reported as follows:

DAILY TONNAGE.

Year.	Spring.	Summer.	Autumn.	Winter.
1918	2,019	2,723	2,370	1,992
1919	2,503	2,129	2,840	2,092
1920[1]	.....	.....	.....	.....

[1] Maximum reported one week, 9,620 tons per day.

In New Jersey and Pennsylvania, through which this route runs, snow removal is not a new thing. This table is, therefore, indicative of the relatively constant freight traffic over roads that are open the year round. Incidentally it illustrates also the decided tendency for the volume of commerce carried over the more important highways to increase.

The movement of rural products, particularly dairy products, is often almost wholly dependent on the highways. In some parts of the East, particularly where manufacturing is the principal business, factory interchange is now largely carried in trucks. Other similar and equally important matters might be mentioned. They would, however, only serve to emphasize the fact that to keep this traffic moving at all seasons of the year is vital. To do so will involve heavy expenditures, which may be open to public attack. On the other hand, to stop this traffic, especially at the present time, when it is admittedly impossible to move it in any other way than over the highways, will involve direct loss to many individuals, who are thereby thrown out of employment, as well as indirect and often unappreciated losses to business of all kinds, which will much more than offset any saving that appears to result from a failure to keep these highways open.

Having these general statements in mind, it may be of interest to note that there is very general recognition of the importance of keeping the heavy traffic routes open. Indeed, the State highway departments in those States where the snow is heavy and the traffic important are all doing whatever they can under the law to meet the situation. The plans of the various highway departments differ somewhat though their actual field methods are very similar. Hence in the subject matter which follows little is said of the field methods used by individual States. On the other hand, the plans of these States for the coming winter may be of interest, as are some of the special features of their work.

PENNSYLVANIA.

Pennsylvania, the leader in all matters of snow removal, is expecting to do more of this work during the approaching winter than has ever been attempted before. Indeed, to that end the State is equipping 75 additional trucks with snow plows and adding to its correlated mechanical facilities and its snow removal organization in a similar proportion. This additional equipment, it is assumed, will be sufficient to enable the State highway department to keep open through routes connecting all of the principal manufacturing centers and connecting with the neighboring States.

Pennsylvania is a mountainous State. Hence the snow removal problem is a difficult one. Moreover, the snowfall is heavy. However, by the liberal use of snow fences—used more liberally in this State than anywhere else in the country—it has been possible to so control drifting that the heavy trucks can keep the roads clear with a minimum of assistance in the way of handwork.

The snow-removal operations in Pennsylvania differ in no essential points from those considered standard in other States and discussed at length in another part of this article, nor is the equipment used by the Pennsylvania State highway department unusual, though the organization probably has more V-shaped plows than are found in other States. It is, however, worthy of note that by reason of the fact that the right of way is kept scrupulously clear of weeds, brush, etc., that obstructions of all sorts are removed wherever possible, and that snow fences are liberally used, the cost of snow removal is reported to be as low as from $50 to $200 per mile.

One feature of the Pennsylvania snow-removal program, not so well known as the methods of actually handling the snow, but deserving of general adoption, is the cooperative arrangement with the Weather Bureau by which the highway department is informed in advance of the approach of storms. This information is at once sent out to the field engineers, who, by reason of the exact information that is furnished both as to the intensity of the coming storm and its probable duration, are the better able to prepare for the emergency.

The patrol system of men, who are employed regularly on the highways, forms a nucleus about which a larger organization can be created whenever condi-

HAND METHODS SUPPLEMENT THE PLOW WHEN THE PILES GROW HIGH.

tions require, and the information given by the Weather Bureau assists the district engineers in determining well in advance of the arrival of the storm whether any special forces will be necessary and insuring that all equipment is in readiness for the emergency. This is of great importance, for it is everywhere agreed that one of the most important matters in fighting a heavy snowfall is getting onto the job in time with the proper forces and that the matter of next importance is the ability to stay on the job as long as the snowfall lasts.

Advance information as to storms assists in both of these matters—in the first particular by furnishing a basis for a determination as to the forces that will be needed and in the second by giving advance information concerning the reserve of forces which must be gotten together to keep up the fight as long as the storm lasts. Too much emphasis can hardly be placed on the value of this information, particularly as to the storms that will continue over a number of days, for a crew can only be depended on for a limited period every day; and if the temperature is low, replacements may have to be made at rather short intervals. On the other hand, it is absolutely essential that the plows be kept running if the final result is to be a cleared highway. Whenever a bad storm is to be faced, the only assurance of success, therefore, lies in ample reserve forces, and Pennsylvania's success in fighting the snow under very difficult conditions can be largely traced to the clear grasp that the State highway department has had of this phase of the matter.

Pennsylvania keeps the public informed as to the condition of the highways. Each patrolman is assigned to a definite section and every day reports to the district head the condition of his section. The district office telegraphs or telephones these reports both to the Weather Bureau at Pittsburgh and Philadelphia and the State highway department, where the information is tabulated and charted, and from these charts information as to the condition of the highways is given to the public either direct or through the Weather Bureau's daily bulletins.

If any point on the designated routes is blocked for more than 24 hours the headquarters organization takes a hand in the matter and men and equipment from other points are thrown in until the men and the equipment available are able to cope with the situation.

The State highway department of Pennsylvania believes that the important trunk-line highways are as important a factor in the Nation's distribution system in the winter as they are in the summer. They are important enough to build and maintain in the summer. They must, therefore, be important enough to keep open during the winter. This is, beyond a doubt, a reasonable point of view and ample defense of the liberal expenditures made to this end.

OHIO LOCAL OFFICIALS DO WORK.

The State highway department of Ohio is limited by law in its snow-removal activities by reason of the fact that all responsibility for snow removal rests on the counties, towns, and townships. The highway department has, however, taken an active interest in the matter of snow removal, has published valuable instructions in regard to this matter, and renders all possible assistance to such counties as will undertake the work. Indeed, the highway department not only loans machinery freely, but will send its own engineers to advise and assist whenever requested to do so.

There is to be a definite effort to keep open the important routes through this State this winter, but as the work must be paid for by the local authorities, the State's activities being confined to efforts to correlate the work in the different local units, to assisting with equipment, and to furnishing such supervision as may be desired by the local authorities, the final result can not be predicted until all of the plans have been completed.

NO DEFINITE PLANS IN INDIANA.

In the State of Indiana the State highway department is fortunate in having ample funds and full authority to use them in any manner that will be of assistance to the traffic and of benefit to the highway. However, snow removal has never been undertaken on a large scale, and it is thought that, generally speaking, the snowfall in this State is not heavy enough to cause much obstruction of traffic. This, coupled with the fact that the State highway department in its present form is a very young organization, explains the fact that no definite plans have as yet been made for handling this winter's snowfall. The head of the highway commission, however, states that the commission has ample authority and ample money to devote to this work and that the principal routes through Indiana will be kept open to traffic this winter.

EXTENSIVE MICHIGAN PROGRAM.

The State highway commission of Michigan did a good deal of snow-removal work last winter and is planning a more extensive program for the coming winter. Indeed, an effort will be made to keep all of the State routes open. In the north, where the snowfall is heavy and the traffic light, the snow will be rolled as often as may be necessary in order to keep the traffic moving. Farther south plows will be operated.

Michigan has already begun the preparations for winter by making a very active effort to get all obstructions cleared from the right of way, tight fences and hedges removed, and wherever possible, snow fences installed. Machinery is also being prepared.

Michigan, like all large States, faces the fact that on her State highway system some routes are of more

TRUCKS IN TANDEM WITH THE SNOW PLOW BETWEEN.

importance than others. The important routes will, of course, receive first attention, and it is fully expected that, no matter what difficulties are encountered, the through routes connecting Michigan's important centers with each other and with the adjoining States will be kept open throughout the winter.

THE ILLINOIS SITUATION.

The State highway department of Illinois is in the unique position of having under its control for maintenance only those sections of the proposed State highway system on which paving has been completed. This gives the State highway department at the present time only two routes of importance—one from Chicago north to the Wisconsin boundary line and the other from Chicago to the Mississippi River at Clinton. The snowfall in Illinois is not heavy. Indeed, only on an average of one year out of three is the fall heavy enough to obstruct traffic. Even then it is the drifting of the snow that generally causes whatever trouble there is. As there are few cuts on the Mississippi River road and none deserving of mention on the road north of Chicago, the State highway department anticipates no trouble with snow but has plenty of equipment to handle the situation should trouble arise.

The State highway department has under its control a good deal of highway; that is in short stretches which are a part of through routes now under construction. Owing to the fact that detours not under State jurisdiction have to be used in order to make any use of these short sections, detours on which it is probable that no snow-removal work will be undertaken, the State engineers hardly expect to find it necessary to handle the snow on these isolated sections during the coming winter.

NEW JERSEY'S PROGRAM.

The State highway department of New Jersey has been developing and steadily increasing its snow-removal program for some years and has plans for further increases for the coming winter. During the winter of 1919–20, 280 miles of State highway were kept clear at an expense of $77,710.43. This represents an average expenditure of $278 per mile. As might be expected, however, this average cost gives only a vague impression of the work of snow removal for the cost varies from considerably less than the average where the fall is light to much larger sums where the fall is heavy and drifting is serious. Thus, near Cranberry, on the main road between New York and Philadelphia, $4,326.99 was spent in keeping a short stretch of highway open during February alone. In this case ice as well as snow had to be removed, the work having been seriously complicated by the drainage conditions in this region.

For the coming winter plans are being laid to keep all of the State highway routes—about 700 miles—open to traffic, and equipment is being prepared to that end. Some snow fence will also be used.

In handling the snow situation in New Jersey it is customary to start clearing on a width of 30 feet or as near to that as can be obtained. The plows are ordered out as soon as from 2 to 3 inches of snow has fallen and are worked 24 hours a day while the snowfall continues. As the winter advances, particularly if the snowfall is heavy and the weather uniformly cold, the width worked over gradually narrows down until only about 18 feet is kept clear. This permits two-way traffic at all times, which is felt to be of importance not only because it facilitates the movement of the traffic but because it prevents the formation of the snow ruts that are so destructive of certain types of pavement.

IN MASSACHUSETTS.

Snow removal in Massachusetts is a new thing, the legislature having only recently appropriated $50,000 to be used in assisting in the removal of the snow on important routes. The Massachusetts law does not contemplate that the State shall bear the whole cost of snow removal, hence, the relatively small appropriation, but appears to contemplate a general supervision of activities, the cost of which will be paid from other than State funds.

Massachusetts, indeed, all of New England, is the seat of numerous large manufacturing enterprises. The freight problem is not, therefore, the long-haul problem, as it is known in most parts of the country, but a problem of plant interchange on a large scale. This arises from the fact that relatively few factories take the raw material delivered from a distance and turn out the completed article of commerce. To illustrate, few shoe factories take the hide, tan it, dye it, etc., and finally convert it into shoes. Rather the hide is tanned at one point, often moved a considerable distance to a dye plant for further treatment, and only sent to the shoe factory for final manipulation. It often happens that the tannery, the dye plant, etc., are owned by the corporation that owns the shoe factory, but the fact that they are separated, often by considerable distances, creates a problem in interplant transportation which resembles the problem of handling partially completed units in a large factory more than it does the problem of the bulk transportation of raw products.

Working on the basis of the facts above outlined as the salient feature in the Massachusetts situation, though by no means overlooking any of the other factors in the traffic situation, the Massachusetts State highway commission has set out to solve the snow-removal problem by cooperative agreement with those interests most directly affected by any closure of these highways—the large factories and the large trucking companies. To these companies, as well as to the larger towns and the cities, the highway commission is pointing out the advantages of a cooperative effort toward keeping the highways clear and securing agreements with such organizations as will cooperate, these agreements covering fixed sections of the routes that are to be kept open. Under these agreements the State will supply the plows and hold them at definite points, where, on notice from the State's engineers, and regardless of the day or the hour, they are to be picked up by the trucks owned by the cooperating agencies and kept on the road as shall be needed in keeping the assigned sections clear. Under this arrangement the cost of the supervision falls to the State, but the cost of operating the trucks is borne by the cooperating agencies. The scheme is unique, but under the peculiar conditions existing in Massachusetts, and with the excellent supervision that the connection of the Massachusetts State highway commission with this enterprise is bound to insure, it ought to prove successful.

CONNECTICUT.

The State Highway Department of Connecticut removes snow from the State highways, paying for the cost from its maintenance funds which are secured from the license fees from automobiles. The State has battled with the snow, with greater or less success, for the past three or four years, and will carry on the work during the coming winter as in the past. Sufficient equipment is available to take care of the ordinary snowfalls, and the labor required will be supplied from the regular forces employed by the maintenance department. Last year snow was removed from about 1,000 miles of road and it is confidently expected that the same program will be carried out this year.

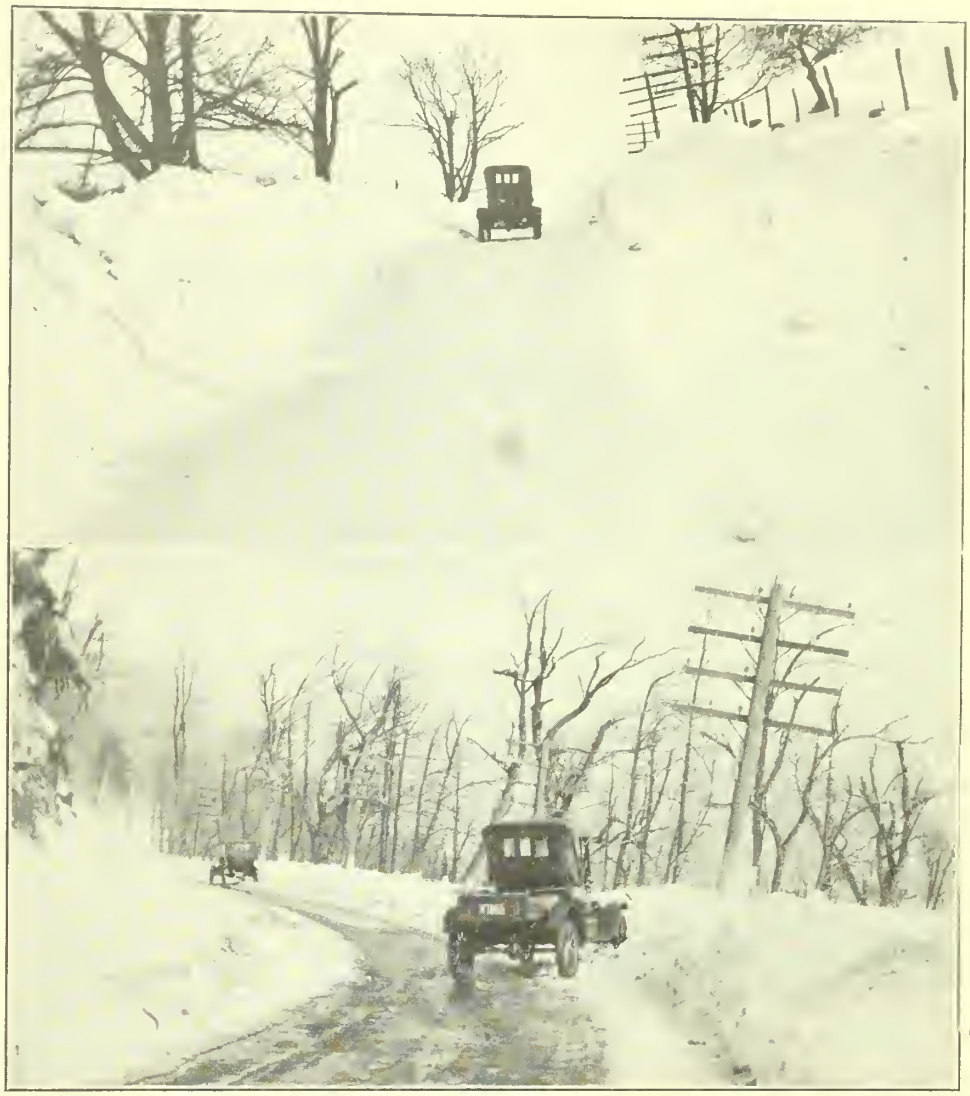
MARYLAND.

Maryland has made no attempt to remove snow in previous years. Except in the mountains of the western section of the State, the snow problem is not a serious one. In that section however the snow fall is heavy and some seasons covers the ground from early fall to late spring. The Roads Commission now recognizes the need for clearing and this year is planning to keep open the roads from Washington, through Baltimore to the Delaware line, the road from Baltimore to Cumberland and Western Maryland, the boulevard from Baltimore to Annapolis, and the roads to Solomons Island and Point Lookout. At least 20 trucks of the four-wheel-drive type will be equipped with plows and held in readiness for the work on these roads.

ON NEW YORK'S ROAD SYSTEM.

The State of New York has the largest State highway system in the United States. Over $200,000,000 have been invested in this system. But, owing to the

fact that the State laws place the responsibility for snow removal on the local authorities, it has, so far, been impossible to devise any method by which this $200,000,000 improvement can be kept at the disposal of the public during the winter months. The commissioner does not believe it a good policy to allow $200,000,000 worth of roads to lie idle from two to three months every year and is willing to assume the responsibility for keeping the important routes open whenever funds are made available, but can do very little toward that end under existing laws.



TOP. AFTER SEVERAL SNOWS IT WILL BE DIFFICULT TO CLEAR THE ROAD UNLESS THE EARLY FALLS HAVE BEEN MOVED WELL BACK. BOTTOM. THE CLEARING AFTER THE FIRST SNOWFALL SHOULD BE WIDE ENOUGH TO ALLOW SPACE FOR THE DISPOSAL OF THE LATER FALLS.

SNOW-REMOVAL METHODS.

The actual work of snow removal that will be done this winter is handled in pretty much the same fashion by all of the States. It is the common and the logical practice to turn this work over to the maintenance department. In most States the maintenance departments are now well organized, and the addition of snow-removal work to the previously assigned duties of the maintenance department has the advantage of making what, for the lower grades of employees, has been a seasonal occupation into a full-time position. In the long run this will have a very beneficial effect, for it will make it possible to obtain and to keep a better grade of men.

The methods used in handling this snow problem are also similar in all of the States. Indeed, they resolve themselves into two distinct groups of activities:

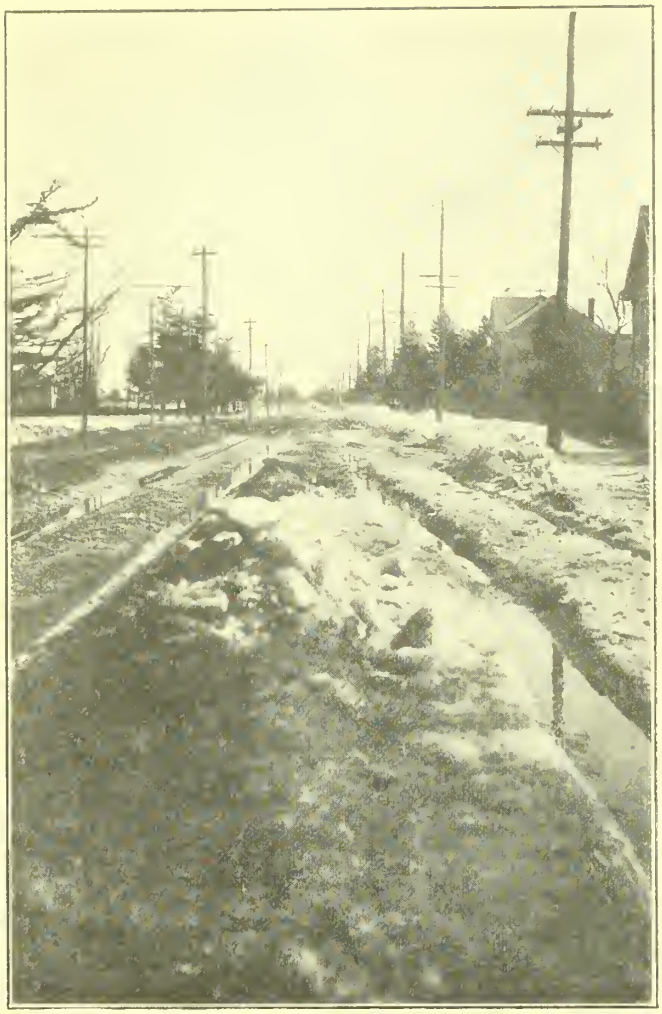
(1) The removal of snow from the highways and
(2) Preventive methods tending to keep it from blowing into the highways in objectionable quantity.

These naturally go hand in hand, but as the expense of removing snow is apt to be greater than the expense of preventing it from accumulating on the roads, the preventive methods will be treated at the greater length.

PREVENTIVE MEASURES.

Snow, of course, falls uniformly and sometimes lies as it falls. More generally, however, there is some wind in connection with a snowfall, and when this is the case there is, depending on the velocity of the wind and the character of the snowflakes, more or less drifting. Snowflakes are carried along by air currents just as sand and silt are carried by water currents. Moreover, the greater the velocity of a wind current the more snow it can carry. And herein lies the cause of drifting, for wherever an air current that is carrying snowflakes is checked some of the snowflakes are, perforce, dropped, and as this continues a drift is formed, the whole process being quite the same as that by which sand bars are formed in water currents.

It should be noted, however, that in general the snow that is moved about by the wind is not raised very far above the surface of the ground. The distance that it is raised depends, of course, on the velocity of the wind, but it is only in exceptional cases that the wind is so high that the snow is carried at an elevation which prevents the control of the area in which it will be deposited.



IF SNOW IS NOT REMOVED RUTS ARE FORMED AND THE DAMAGE TO THE HIGHWAY IS OFTEN MUCH GREATER THAN THE COST OF SNOW REMOVAL.

Snowdrifts are formed on the lee side of obstructions. This naturally follows from the fact that back of such obstructions there is a body of relatively quiet air. Indeed, the velocity of an air current may be affected for as much as 10 times the height of such low obstructions as fences, hedges, etc. From this it naturally follows that where snow is being carried by wind, low obstructions will clear the air current of snow by causing it to be deposited in a relatively quiet space back of these obstructions.

This matter has been treated at some length because of its relation to all of the means that must be adopted for preventing the formation of drifts. These begin with the removal from the right of way of everything that can cause drifting. Weeds are the most common source of trouble These should be carefully cut down and removed, for a growth of weeds or high grass, even if no more than a foot or two high, will cause drifting whenever the wind is right. Moreover, this applies even to such places as the tops of fills that would otherwise blow clear. Too much emphasis can hardly be placed on this matter, for more drifting is caused by weeds and brush allowed to accumulate along the roadway than in any other way. The weeds should, of course, be kept down by constant trimming, but if this has not been done they should at least be cleared away in the autumn and the right of way left unobstructed during the winter months.

HEDGES, FENCES, AND TREES.

Next in order of importance as causes of drifts on the highways are the hedges. These should be removed wherever experience has shown that they cause trouble. A hedge will, of course, cause drifting whenever the wind is right, but there are many regions where the winds that carry snow are so constantly from one direction that only a relatively small fraction of the hedges need to be removed to correct practically all of the trouble originating from this cause.

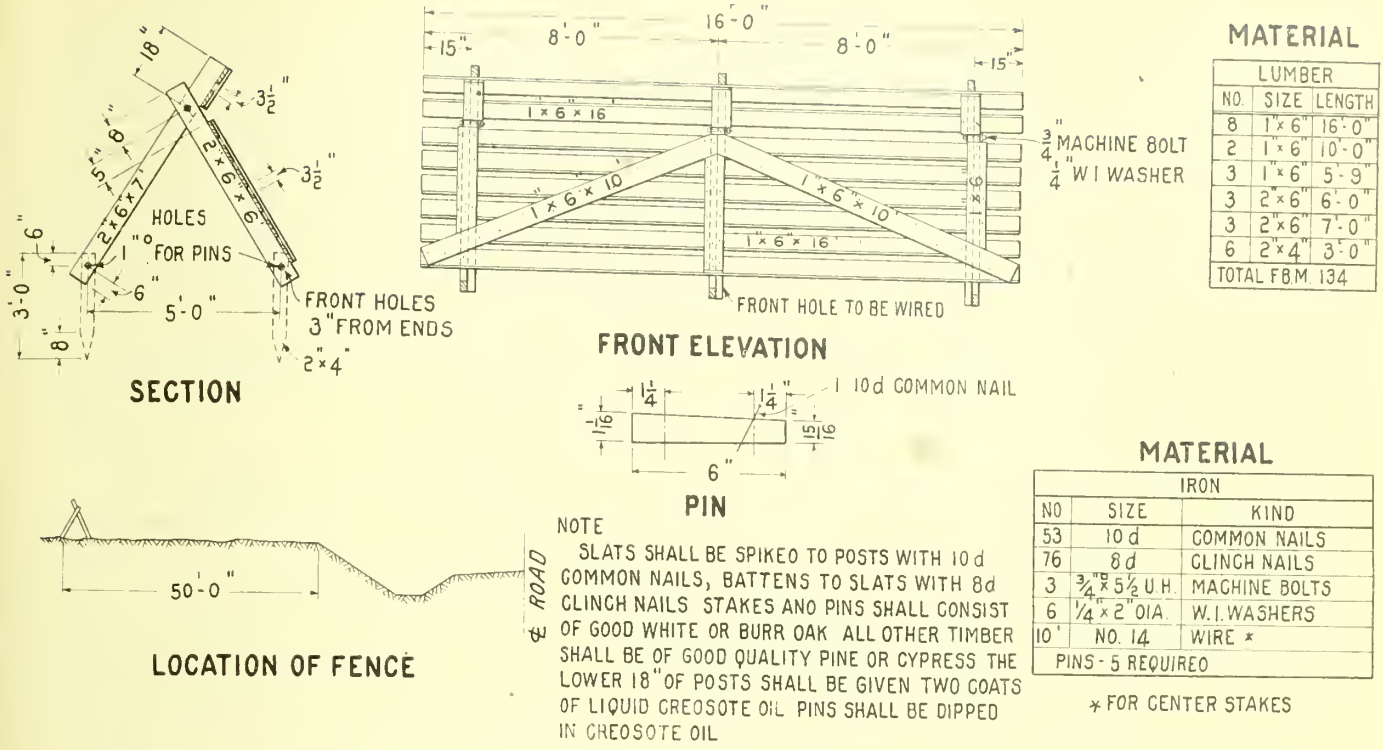
Stone fences, rail fences, picket fences, indeed, all of the tight fences, can and often do cause drifting. To reduce drifting to a minimum, such fences should therefore be taken out and wire fences erected in their places, for wire fences, being open, offer no obstruction to the wind and so do not create a condition under which snow will be deposited.

Rows of trees sometimes cause drifts to form. Where this is the case it will generally suffice to trim the branches well above the ground. Sometimes, however, this is not sufficient, and the trees themselves must be taken out. At this point measures of snow removal come into conflict with roadside beautification and home or town improvement and a problem is created that can not be solved with the snow problem solely in mind. Indeed, this same applies to some extent to the removal of fences and hedges, and, in practice, it will be found that in spite of the obvious advantage of removing such obstructions there may arise even more patent disadvantages which will prevent the complete elimination of all of these sources of trouble.

Besides the above causes of drifting there are conditions lying in the topography of the country and in the manner in which roads have been built that tend to cause drifting. A hill may affect the air currents a good deal. A cut may be so placed that it catches the flying snow. Matters of this kind can not be corrected by eliminating the cause of the drifting, however, a good deal can be done by erecting snow fences.

As has been stated above, the snow that is carried by the wind is usually carried near the ground. Where cuts drift full, or where the general contour of the country causes drifting, snow fences may be so placed that the air currents will be cleared of snow before they pass over the road.

To accomplish this, such fences should be erected on the windward side of the road and from 50 to 60



MATERIAL

LUMBER		
NO.	SIZE	LENGTH
8	1"×6"	16'-0"
2	1"×6"	10'-0"
3	1"×6"	5'-9"
3	2"×6"	6'-0"
3	2"×6"	7'-0"
6	2"×4"	3'-0"
TOTAL F.B.M. 134		

MATERIAL

IRON		
NO	SIZE	KIND
53	10 d	COMMON NAILS
76	8 d	CLINCH NAILS
3	3/4"×5 1/2 U.H.	MACHINE BOLTS
6	1/4"×2" DIA.	W.I. WASHERS
10'	NO. 14	WIRE *
PINS - 5 REQUIRED		

* FOR CENTER STAKES

NOTE
SLATS SHALL BE SPIKED TO POSTS WITH 10 d COMMON NAILS, BATTENS TO SLATS WITH 8d CLINCH NAILS STAKES AND PINS SHALL CONSIST OF GOOD WHITE OR BURR OAK ALL OTHER TIMBER SHALL BE OF GOOD QUALITY PINE OR CYPRESS THE LOWER 18" OF POSTS SHALL BE GIVEN TWO COATS OF LIQUID CREOSOTE OIL PINS SHALL BE DIPPED IN CREOSOTE OIL

PORTABLE SNOW FENCE DESIGNED BY THE OHIO STATE HIGHWAY DEPARTMENT.

feet distant. These fences may be either permanent or portable, but as rural highways quite generally run through land that is used for agricultural purposes, the portable fences have the wider adaptability in highway work, for they can be set up after all crops are removed from the land and removed in the spring before the land must be worked for the next year's crop.

Snow fences are generally either of the "board fence" type (see figure) or of the picket type. The permanent fences are generally of the board type. Eight 6-inch boards, separated from 2 to 4 inches on the nailing strips, make a very satisfactory fence for this purpose, the portable fence of this type differing from the permanent installation only in that it is made up in sections of convenient length and held in place by stakes or driven posts rather than by set posts.

Picket fences are often used where a portable fence is required. The best fence of this kind is one made of light pickets held in place by a number of strands of heavy wire. Such fences can be readily erected on driven posts and when out of use rolled up and stacked where they will be out of the way.

WHERE PREVENTIVE MEASURES FAIL.

After all of these preventive measures have been resorted to, there will still remain to be handled all of the snow that lies as it falls and such minor drifting as can not be economically handled by the erection of fences and this may amount to a good deal, for, ranging from little or nothing in the southern part of the country, the normal snowfall increases to the north, until in many parts of the northeastern, northwestern, and northern Lake regions it exceeds 100 inches a year. Indeed, in the regions where there are heavy snowfalls the problem of keeping the highways clear is a serious one even after all preventable drifting has been eliminated, and it is not an easy one to handle though the snowfall is only moderate.

There are really only two methods of keeping roads open to traffic where the snow is heavy—the compaction method and the removal method.

OPENING ROADS BY COMPACTING THE SNOW.

Solving the snow problem by compaction consists of rolling the road after every snowfall with a roller 6 or 8 feet in diameter and from 10 to 12 feet long. To insure that the roller shall work well, the ends must be closed. Two widths should be rolled so that vehicles can pass without either one getting off of the compacted snow.

This method does very well where the traffic is light and is composed principally of horse-drawn vehicles and possibly a few light automobiles. It is not, however, satisfactory for roads where the traffic is heavy, and is wholly unsatisfactory where many automobiles or heavy trucks must use the highway, for such vehicles are apt to lose traction, even in well-compacted snow, and to spin their drive wheels until they are as effectively stalled as on a muddy road.

This system has the added disadvantage of facilitating the formation of ruts. Even compacted

snow cuts away rapidly, and as there is a tendency for each vehicle to follow its predecessor bad ruts are soon formed. Indeed, these often cut clear through to the underlying pavement, which, because all of the traffic is concentrated in two narrow wheel tracks, may be very materially damaged thereby.

It should not, however, be assumed that these snow ruts are formed only when the snow is compacted. As a matter of fact they are still more readily formed where nothing at all is done toward dealing with the snow. Indeed, one of the best reasons for removing the snow from the highways lies in the fact that where this is not done, if the traffic is of much volume, snow ruts are formed, and the damage thereby done the highway is often much greater than the cost of removing the snow would been.

REMOVAL NECESSARY ON SOME ROADS.

Where the roads must be kept clear and the traffic is such that compacting the snow is not sufficient, there remains nothing but the removal of the snow. This may be accomplished by the use of plows or by hand. Sometimes rotary plows are used, but as yet they have not been commonly adopted for this work in this country. Ultimately the writer believes that the heavier snowfalls will be handled by some form of apparatus resembling the modern elevator grader. Such a machine might be readily designed to clear the full width of the highway at a single cut and, by using a fast-moving belt, to discharge the snow well away from the line of travel and where it would tend to prevent rather than to stimulate further drifting.

The present practice in snow removal is, however, to push the snow off of the highway by means of blades similar to those used on road graders. Indeed, road graders are frequently used for this work, though the more common practice now is to fasten a heavy blade ahead of a heavy truck (the four-wheel drive type being preferred for this work) and to use the powerful driving force of the truck to push the snow off of the highway. Sometimes, and this applies particularly where the fall of snow is heavy, a second truck is used, this truck being hitched ahead of the truck that carries the plow. In this way a heavier plow can be used and the deeper snow thrown aside.

Operating in this fashion, all equipment must be kept available at all times and must be set in operation whenever the necessity arises, regardless of the day or the hour. The present practice is to start work as soon as from 2 to 3 inches of snow has fallen and to continue operations as long as the fall continues. The snow may be moved from the center to both sides, but in order to prevent drifting it is better to move all of the snow to the leeward side of the road. Even then some drifting may result from piling up the snow, but much less than will result from any piling of the snow on the windward side of the road.

The first clearings of the season should be wide enough. Indeed, the best practice is to clear at least 10 feet more than the traveled way. If an 18-foot road is being cleared this will mean that one cut should be made beyond each edge of the road surfacing where the snow is thrown to both sides, or that two cuts should be run beyond the edge of the pavement where all the snow is piled on the lee side of the road. As the season advances, this extra space will be used to store the later snowfalls. Therefore, though it appears during the early part of the winter that cutting this extra width is a considerable inconvenience, it will usually prove a time saver as well as a money saver in the end.

GET TRUCK ON JOB EARLY.

The success or failure of this system depends on getting the trucks onto the job early enough and keeping them there regardless of weather conditions. A well-driven truck can handle about 10 miles of highway. It should always be in good condition when sent out on work of this sort and particularly so when sent out on night work. At least one and preferably two assistants should accompany the driver. If a heavy blanket of snow is being moved a half dozen men with shovels should go out with the truck. Under normal operating conditions, a well-handled truck should make one cut an hour, but as it will take four full cuts to clear the necessary width at the beginning of the seasons and generally three during the later months, it will be clear that the truck must be kept in constant operation as long as the storm continues if the final result is to be an open road. However, if the trucks are set to work early and kept at work regardless of the weather, it will not often happen that other methods have to be resorted to.

On the other hand, occasions will arise when, due to high winds and the failure to provide proper snow fences, cuts will drift full in spite of all that the trucks can do; or, possibly, it might be more correct to say that, because cuts are relatively narrow if the snow drifts into them rapidly, the trucks will often be unable to find the space to store the snow that must be handled if such cuts are to be kept clear. When this happens, as it will from time to time, the usual method is to put men in with shovels and clear away the drift by hand. Work of this kind is expensive, so the temptation to clear a minimum width is strong, but the most economical width is not necessarily the minimum that will serve the traffic. If the major portion of snow removal is being handled by the trucks, in which case any further snow falling on the road must be pushed to one side as it falls, the cleared width should be wide enough to give the trucks a chance to handle the later falls when they come. Otherwise the cuts will be blocked almost at once and hand shoveling must be resorted to whenever there is a snowfall.

[Concluded on page 32.]

LAYING OUT CIRCULAR CURVES BY DEFLECTIONS FROM THE P. I.

By T. F. HICKERSON, Professor of Civil Engineering, University of North Carolina.

THE writer hopes that the tables based upon formulae given below will fill the long-felt need of a simple and time-saving method for laying out circular curves by deflections from the point of intersection of the tangents (the P. I.), thus avoiding the trouble of moving the instrument and resetting the vernier.

Referring to figure 1, P is any point on the circular arc CB and A is the point of intersection of the tangents. Also, C is the point of curve (P. C.), and B is the point of tangent (P. T.). Lines from points A and O to point P make angles of Θ and α with the line AO, these angles being plus when measured above AO and minus when below it. PN is drawn perpendicular to AO. The deflection angle is called Δ

$$Tan\,\Theta = \frac{PN}{AN} = \frac{R\sin\alpha}{E + R - R\cos\alpha} = \frac{R\sin\alpha}{R(\sec\tfrac{1}{2}\Delta - 1) + R - R\cos\alpha}$$

Hence,

$$\tan\Theta = \frac{\sin\alpha}{\sec\tfrac{1}{2}\Delta - \cos\alpha} \qquad (1)$$

Formula (1) shows that for a given value of Δ, the angle Θ is independent of the radius of the curve or the length of curve.

Imagine the curve divided into *10 equal parts*, then formula (1) gives the deflections to these points of division as follows:

$$\alpha = \tfrac{4}{10}\Delta,\ \tan\Theta_1 = \frac{\sin\tfrac{4}{10}\Delta}{\sec\tfrac{1}{2}\Delta - \cos\tfrac{4}{10}\Delta},$$

$$\alpha = \tfrac{3}{10}\Delta,\ \tan\Theta_2 = \frac{\sin\tfrac{3}{10}\Delta}{\sec\tfrac{1}{2}\Delta - \cos\tfrac{3}{10}\Delta},$$

$$\alpha = \tfrac{2}{10}\Delta,\ \tan\Theta_3 = \frac{\sin\tfrac{2}{10}\Delta}{\sec\tfrac{1}{2}\Delta - \cos\tfrac{2}{10}\Delta},$$

$$\alpha = \tfrac{1}{10}\Delta,\ \tan\Theta_4 = \frac{\sin\tfrac{1}{10}\Delta}{\sec\tfrac{1}{2}\Delta - \cos\tfrac{1}{10}\Delta},$$

$$\alpha = 0,\ \Theta_5 = 0$$
$$\alpha = -\tfrac{1}{10}\Delta,\ \Theta_6 = -\Theta_4$$
$$\alpha = -\tfrac{2}{10}\Delta,\ \Theta_7 = -\Theta_3$$
$$\alpha = -\tfrac{3}{10}\Delta,\ \Theta_8 = -\Theta_2$$
$$\alpha = -\tfrac{4}{10}\Delta,\ \Theta_9 = -\Theta_1$$
$$\alpha = \tfrac{5}{10}\Delta,\ \Theta_{10} = -\tfrac{1}{2}(180 - \Delta)$$

Values of Θ_1, Θ_2, Θ_3, etc., computed by means of the above formulae for different values of Δ show that they change *uniformly* with Δ; so that interpolation gives results as closely as one minute for ranges of 1° in Δ.

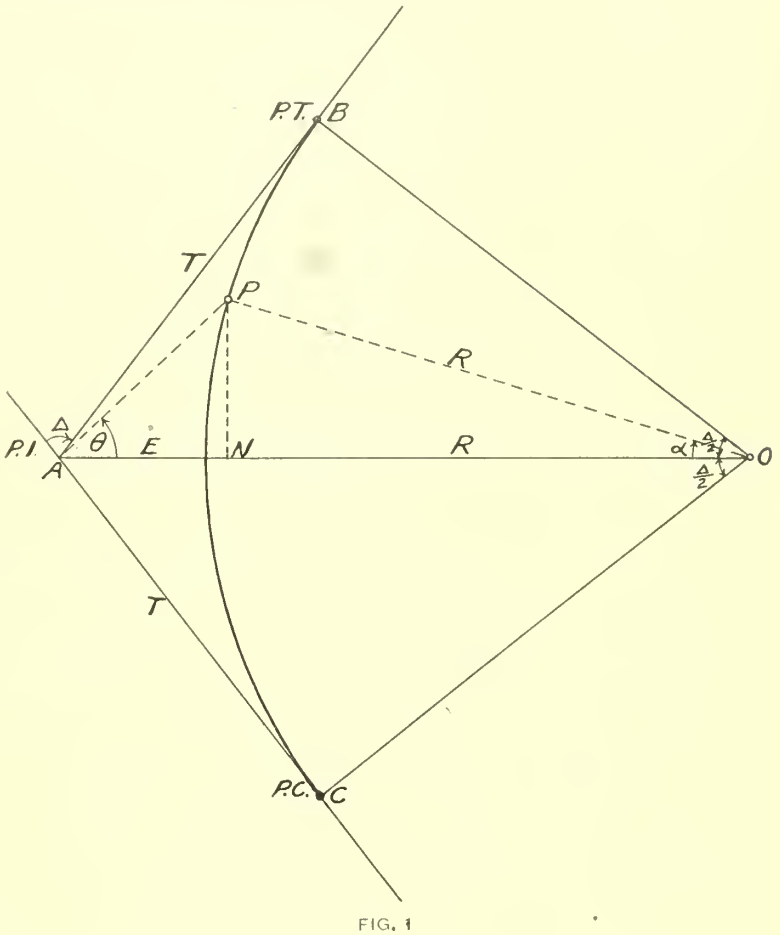


FIG. 1

For convenience in laying out curves without resetting the vernier, these directions to points on the curve are referred to the first tangent, the line CA produced.

Instrument at the P. I., and vernier reading $\Delta°$ on the P. T., we have:

Deflection to point (1) $= \Delta + \tfrac{1}{2}(180° - \Delta) - \Theta_1$
$= 90° + \tfrac{1}{2}\Delta - \Theta_1$
(2) $= 90° + \tfrac{1}{2}\Delta - \Theta_2$
(3) $= 90° + \tfrac{1}{2}\Delta - \Theta_3$
(4) $= 90° + \tfrac{1}{2}\Delta - \Theta_4$
(5) $= 90° + \tfrac{1}{2}\Delta$
(6) $= 90° + \tfrac{1}{2}\Delta + \Theta_4$
(7) $= 90° + \tfrac{1}{2}\Delta + \Theta_3$
(8) $= 90° + \tfrac{1}{2}\Delta + \Theta_2$
(9) $= 90° + \tfrac{1}{2}\Delta + \Theta_1$
(10) $= 180°$.

It should be noted that the following pairs of deflections add up to $180° + \Delta°$: (1) + (9), (2) + (8), (3) + (7), and (4) + (6).

Using the above formulae, deflection tables have been compiled for all values of the angle Δ varying

by 1° from 3° to 128°. This covers all cases that are likely to occur in locating curves for roads and streets.

Figure 2 is a graphical verification of the fact that for a fixed Δ the deflections to points of equal division on a curve remain constant for any length of the curve. This makes the method perfectly general.

The order of procedure in laying out a curve is as follows: (1) Set up the instrument at the P. I., back sight on the first tangent with vernier reading 0°, reverse the telescope, unclamp the vernier, and fix the line of sight on the second tangent, the vernier giving the deflection angle $\Delta°$; (2) decide what length of curve to use (determined usually either by the desired external distance E or the tangent length T); (3) compute T and E, using either the well-known table of tangents and externals for a 1° curve, or, preferably, the tangents and externals for a 100-foot curve (Table II); (4) lay off the tangent length locating the end of the curve (the P. T.); (5) divide the length of curve by 10 and locate each of the 10 points, or every other one, or every third one, etc., depending upon how many are needed to properly define the curve, by starting at the P. T. (or P. C.) and getting the intersection of the end of the chord with the line of sight from the instrument at the P. I., according to deflections read directly from the tables (Table I).

The middle point, or the fifth point of the curve, can not be located precisely by intersections since the end of the chord would be moved in an arc tangent to the line of sight. This point can be located exactly and independently by measuring the external distance E from the P. I., and this serves as a check. If only the second, fourth, sixth, eighth, and tenth points are located, then it is not necessary to know E.

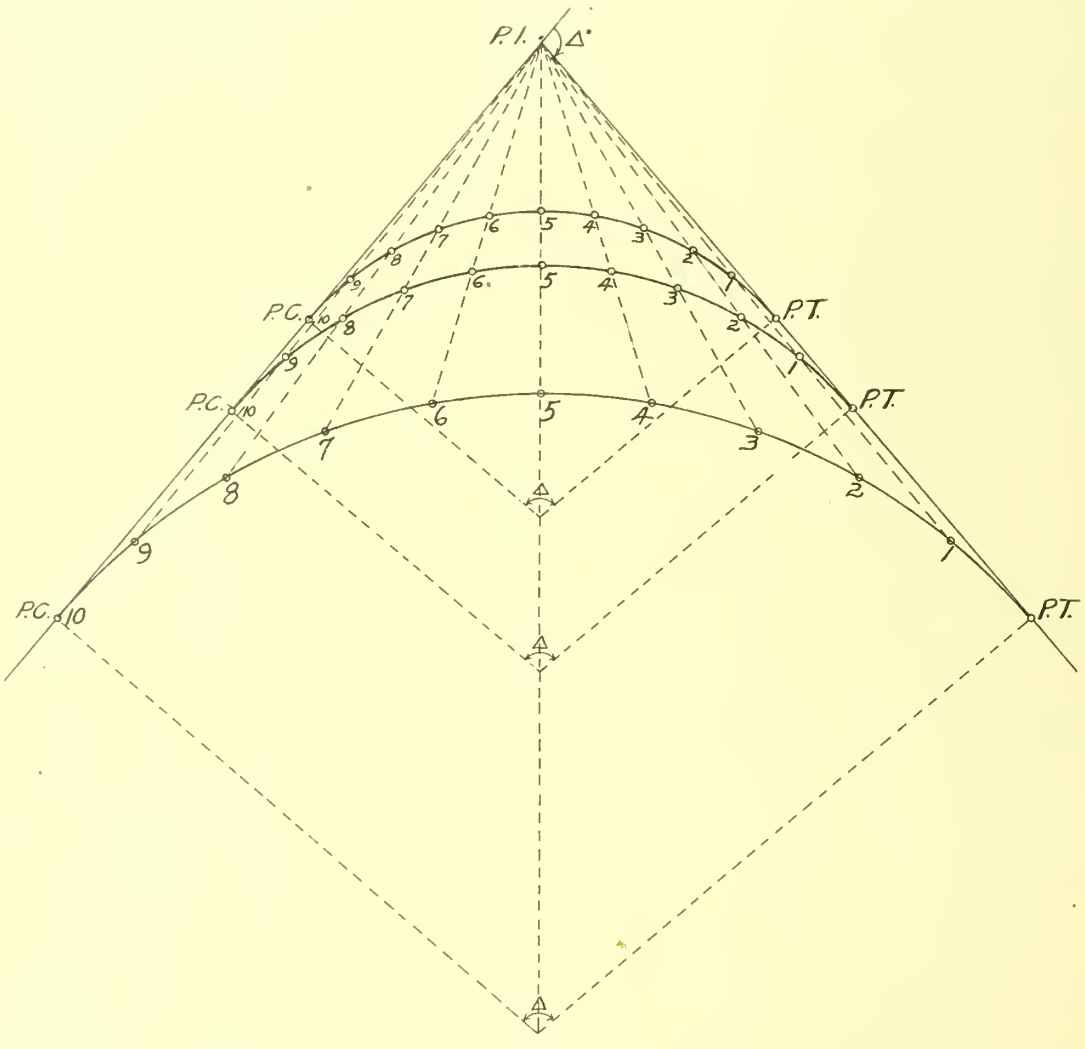


FIG. 2.

The beginning of the curve (the P. C.) is located as the tenth point by a deflection, which is always 180°. The station number of the P. C. is known, hence its location can be checked by measuring the plus distance back to the preceding station. This method avoids measuring the tangent distance from the P. I. in order to locate the P. C.

It should be noted that the curve can be located by starting at the P. C. instead of the P. T., the deflection to the first point being the same as that to the ninth point as given by Table I, etc.

If part of the curve is not visible from the P. I., say, that beyond the sixth point, the instrument may be moved to the sixth point and the remaining points located by deflections from any preceding chord. Thus, suppose the instrument is set up at the sixth point and a back sight is taken to the second point, vernier reading 0°; then, after inverting the telescope, the proper deflection to locate the seventh point is:

$$\frac{4\Delta}{20}+\frac{1\times\Delta}{20}=\frac{5\Delta}{20};$$

the deflection to the eighth point is

$$\frac{4\Delta}{20}+\frac{2\times\Delta}{20}=\frac{6\Delta}{20}, \text{ etc.}$$

In general, if the instrument is set up at the rth point of the curve and a back sight is taken to the kth point, then the deflection to the $(r+1)$th point equals

$$\frac{(r-k)\Delta}{2\times10}+\frac{1\times\Delta}{2\times10};$$

the deflection to the $(r+2)$th point equals the preceding plus $\frac{\Delta}{2\times10}$, etc.

If the P. I. is inaccessible or invisible from the curve, then the instrument is set up again at the P. C. and the points of equal division along the curve are located by deflections from the tangent. Thus if the curve is divided into 10 equal parts the deflections are as follows:

Deflection to first point $=\frac{\Delta}{2\times10}$

Deflection to second point $=\frac{2\Delta}{2\times10}$

Deflection to third point $=\frac{3\Delta}{2\times10}$, etc.

Recently the writer was in charge of a party that surveyed 22 miles of Federal-aid highways in hilly and mountainous country, and the following facts were observed: (1) Not a single case of inaccessible P. I. occurred; (2) along 86 per cent of the curves the P. I. was visible throughout; (3) in only 42 per cent of the curves was the P. T. visible from the P. C. This means that 86 per cent of the curves could have been laid out completely with the instrument set only once (at the P. I.), whereas 58 per cent of them actually required the instrument to be set up three times. The first 11 miles was in fairly open country along the general direction of an old road. Here 96 per cent of the curves were visible throughout from the P. I., but 70 per cent of the P. T. points were not visible from the P. C. The other 11 miles of the survey was partly in a dense forest and not along an old road.

Aside from the time saved in not having to move the instrument, another step in the usual operation of laying out a curve is avoided, and that is the tangent distance is not measured form the P. I. in order to locate the P. C. Curves laid out by the usual method begin and end with subchords of unequal length. This makes the deflections rather tedious to compute. The errors are cumulative, and the writer has seen the best of transit men waste time in trying to find the little error that prevented the final check.

The resident engineer can pick up the P. I. more easily than any other point, and he would find it convenient to realign the curve by deflections from this position while construction is going on, since it is apt to be beyond the grade stakes and not disturbed.

The points on the curve established by deflections according to the proposed new method are at equal and integral distances apart, but they are not full stations. The writer believes the advantages of full-station points are largely imaginary. However, the chainmen can easily locate full station points on their return trip from the P. C. to the P. T. by offsets

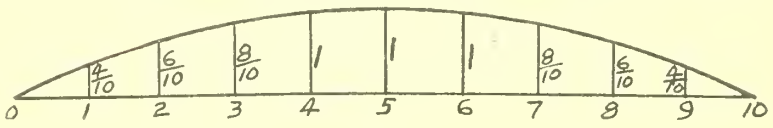


FIG. 3.

from the equal chords. The middle ordinate of the equal chords can be found in Table III, which has been compiled by the writer for the purpose. In this connection it should be remembered that middle ordinates vary practically as the square of the chords; and for any chord, the ordinates vary practically as those of a parabola. (See fig. 3.) Thus, if the middle ordinate is 1 foot the ordinate (or offset) at a point two-tenths of the chord length from the end of the chord is 0.6 foot. The middle ordinate in practice is usually less than 1 foot as will be seen later.

Before proceeding with an illustration, Table II will be explained. This table gives the externals, tangents, radii, and degree of curve for circular arcs of 100 feet in length according to values of the deflection angle ranging from 1° to 128°. It is offered as a substitute for the tables giving the functions of a 1° curve. The following formulae were used in computing the values in Table II:

$$D=\frac{100\Delta}{L}=\frac{100\Delta}{100}=\Delta$$

$$R=\frac{5729.578}{D}$$

$$T=R\tan\tfrac{1}{2}\Delta=\frac{5729.578}{\Delta}\tan\tfrac{1}{2}\Delta$$

$$E=R\tan\tfrac{1}{2}\Delta=\frac{5729.578}{\Delta}\operatorname{ex\,sec}\tfrac{1}{2}\Delta$$

For curves longer than 100 feet the tabular values of the external, tangent, and radius must be multiplied, and the degree of curve divided by the ratio of the given curve length to 100. For example, suppose Δ is 24° and the length of curve to be used is 400 feet, then

$$E=5.334\times4=21.3,\ T=50.744\times4=203.0,\ D=\frac{24}{4}=6°,$$
$$R=238.8\times4=955.2.$$

TABLE I.—*Deflections from the P. I. to points of equal division along circular curves.*

Points	△= 12°00′	Diff. 1′.	△= 12°30′.	Diff. 1′.	△= 13°00′.	Diff. 1′.	△= 14°.	Diff. 1′.	△= 15°.	Diff. 1′.	△= 16°.	Diff. 1′.	△= 17°.	Diff. 1′.	△= 18°.	Diff. 1′.	△= 19°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	12 09	+1.00	12 39	+1.06	13 10	+1.01	14 10	+1.01	15 11	+1.01	16 12	+1.01	17 13	+1.01	18 13	+1.01	19 14	+1.01
3	12 48	+1.06	13 20	+1.06	13 51	+1.06	14 55	+1.06	15 59	+1.06	17 03	+1.06	18 07	+1.06	19 11	+1.06	20 15	+1.06
2	14 41	+1.22	14 17	+1.22	15 53	+1.21	17 06	+1.21	18 19	+1.21	19 32	+1.21	20 44	+1.21	21 57	+1.21	23 10	+1.21
4	21 18	+1.73	22 10	+1.71	23 01	+1.71	24 44	+1.69	26 25	+1.69	28 06	+1.67	29 46	+1.65	31 25	+1.64	33 04	+1.62
5	96 00	+ .50	96 15	+ .50	96 30	+ .50	97 00	+ .50	97 30	+ .50	98 00	+ .50	98 30	+ .50	99 00	+ .50	99 30	+ .50
6	170 42	− .73	170 20	− .71	169 59	− .71	169 16	− .69	168 35	− .69	167 54	− .67	167 14	− .65	166 35	− .64	165 56	− .62
7	177 19	− .22	177 13	− .22	177 07	− .21	176 54	− .21	176 41	− .21	176 28	− .21	176 16	− .21	176 03	− .21	175 50	− .21
8	179 12	− .06	179 10	− .06	179 09	− .06	179 05	− .06	179 01	− .06	178 57	− .06	178 53	− .06	178 49	− .06	178 45	− .06
9	179 51	− .00	179 51	− .00	179 50	− .01	179 50	− .01	179 49	− .01	179 48	− .01	179 47	− .01	179 47	− .01	179 46	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

Points.	△= 20°.	Diff. 1′.	△= 21°.	Diff. 1′.	△= 22°.	Diff. 1′.	△= 23°.	Diff. 1′.	△= 24°.	Diff. 1′.	△= 25°.	Diff. 1′.	△= 26°.	Diff. 1′.	△= 27°.	Diff. 1′.	△= 28°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	20 15	+1.01	21 16	+1.01	22 16	+1.01	23 17	+1.01	24 18	+1.01	25 18	+1.01	26 19	+1.01	27 20	+1.01	28 20	+1.01
2	21 19	+1.06	22 22	+1.06	23 26	+1.06	24 30	+1.06	25 33	+1.06	26 37	+1.06	27 41	+1.06	28 45	+1.06	29 48	+1.06
3	24 22	+1.20	25 34	+1.20	26 46	+1.20	27 58	+1.20	29 10	+1.20	30 22	+1.19	31 33	+1.19	32 44	+1.19	33 56	+1.19
4	34 41	+1.60	36 17	+1.60	37 53	+1.57	39 27	+1.55	41 00	+1.54	42 33	+1.52	44 04	+1.51	45 35	+1.48	47 04	+1.48
5	100 00	+ .50	100 30	+ .50	101 00	+ .50	101 30	+ .50	102 09	+ .50	102 30	+ .50	103 00	+ .50	103 30	+ .50	104 00	+ .50
6	165 19	− .60	164 43	− .60	154 07	− .57	163 33	− .55	163 00	− .54	162 27	− .52	161 56	− .51	161 25	− .48	160 56	− .48
7	175 38	− .20	175 26	− .20	175 14	− .20	175 02	− .20	174 50	− .20	174 38	− .19	174 27	− .19	174 16	− .19	174 04	− .19
8	178 41	− .06	178 38	− .06	178 34	− .06	178 30	− .06	178 26	− .06	178 23	− .06	178 19	− .06	178 15	− .06	178 12	− .06
9	179 45	− .01	179 44	− .01	179 44	− .01	179 43	− .01	179 42	− .01	179 42	− .01	179 41	− .01	179 40	− .01	179 40	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

Points.	△= 29°.	Diff. 1′.	△= 30°.	Diff. 1′.	△= 31°.	Diff. 1′.	△= 32°.	Diff. 1′.	△= 33°.	Diff. 1′.	△= 34°.	Diff. 1′.	△= 35°.	Diff. 1′.	△= 36°.	Diff. 1′.	△= 37°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	29 21	+1.01	30 22	+1.01	31 23	+1.01	32 23	+1.01	33 24	+1.01	34 24	+1.01	35 25	+1.01	36 26	+1.01	37 26	+1.01
2	30 52	+1.06	31 55	+1.06	32 59	+1.06	34 02	+1.06	35 06	+1.06	36 09	+1.06	37 13	+1.06	38 16	+1.06	39 19	+1.06
3	35 07	+1.19	36 18	+1.18	37 29	+1.18	38 39	+1.17	39 49	+1.17	41 00	+1.17	42 10	+1.17	43 20	+1.17	44 30	+1.16
4	48 33	+1.46	50 00	+1.44	51 26	+1.43	52 52	+1.41	54 17	+1.39	55 40	+1.38	57 03	+1.35	58 24	+1.34	59 44	+1.33
5	104 30	+ .50	105 00	+ .50	105 30	+ .50	106 00	+ .50	106 30	+ .50	107 00	+ .50	107 30	+ .50	108 00	+ .50	108 30	+ .50
6	160 27	− .46	160 00	− .44	159 34	− .43	159 08	− .41	158 43	− .39	158 20	− .38	157 57	− .35	157 36	− .34	157 16	− .33
7	173 53	− .19	173 42	− .18	173 31	− .18	173 21	− .17	173 11	− .17	173 00	− .17	172 50	− .17	172 40	− .17	172 30	− .16
8	178 08	− .06	178 05	− .06	178 01	− .06	177 58	− .06	177 54	− .06	177 51	− .06	177 47	− .06	177 44	− .06	177 41	− .06
9	179 39	− .01	179 38	− .01	179 37	− .01	179 37	− .01	179 36	− .01	179 36	− .01	179 35	− .01	179 34	− .01	179 34	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

Points.	△= 38°.	Diff. 1′	△= 39°.	Diff. 1′.	△= 40°.	Diff. 1′.	△= 41°.	Diff. 1′.	△= 42°.	Diff. 1′.	△= 43°.	Diff. 1′.	△= 44°.	Diff. 1′.	△= 45°.	Diff. 1′.	△= 46°.	Diff. 1′.
	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′	° ′	′
1	38 27	+1.01	39 28	+1.01	40 29	+1.01	41 29	+1.01	42 30	+1.01	43 30	+1.01	44 31	+1.01	45 32	+1.01	46 32	+1.01
2	40 22	+1.05	41 26	+1.05	42 29	+1.05	43 32	+1.05	44 35	+1.05	45 38	+1.05	46 41	+1.05	47 44	+1.05	48 47	+1.05
3	45 39	+1.16	46 49	+1.15	47 58	+1.15	49 07	+1.15	50 16	+1.15	51 25	+1.14	52 33	+1.14	53 41	+1.14	54 49	+1.13
4	61 04	+1.31	62 23	+1.30	63 41	+1.28	64 58	+1.27	66 14	+1.25	67 29	+1.24	68 43	+1.23	69 57	+1.21	71 10	+1.20
5	109 00	+ .50	109 30	+ .50	110 00	+ .50	110 30	+ .50	111 00	+ .50	111 30	+ .50	112 00	+ .50	112 30	+ .50	113 00	+ .50
6	156 56	− .31	156 37	− .30	156 19	− .28	156 02	− .27	155 46	− .25	155 31	− .24	155 17	− .23	155 03	− .21	154 50	− .20
7	172 21	− .16	172 11	− .15	172 02	− .15	171 53	− .15	171 44	− .15	171 35	− .14	171 27	− .14	171 19	− .14	171 11	− .13
8	177 38	− .05	177 34	− .05	177 31	− .05	177 28	− .05	177 25	− .05	177 22	− .05	177 19	− .05	177 16	− .05	177 13	− .05
9	179 33	− .01	179 32	− .01	179 31	− .01	179 31	− .01	179 30	− .01	179 30	− .01	179 29	− .01	179 28	− .01	179 28	− .01
10	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00	180 00	.00

This table gives conveniently a length of curve that will always be a multiple of 10. The chords therefore will always be an integral number of feet in length.

Example 1.

Given $\Delta = 40° 00'$; P. I. at Sta. 62 + 11.8.
From Table II, $L = 100$, $E = 9.193$, $T = 52.135$, $D = 40°$.

Suppose local conditions are such that E should equal 16 feet approximately. Hence, ratio $= \frac{46}{9.2} = 5$.
$L = 500$, $E = 46.0$, $T = 260.7$, $D = 8°$.
$\frac{500}{10} = 50$ = length of each chord to be applied 10 times.

P. I. = 62 + 11.8
T. = 2 + 60.7
P. C. = 59 + 51.1
L. = 5
P.T. = 64 + 51.1

For $\Delta = 40° 00'$, the deflections are given directly in Table I, as follows:

Point.	Station.	Deflection.
P. T.	64+51.1	Δ
First	64+01.1	40° 29′
Second	63+51.1	42° 29′
Third	63+01.1	47° 58′
Fourth	62+51.1	63° 41′
Fifth	62+01.1 (E=46)	110° 00′
Sixth	61+51.1	156° 19′
Seventh	61+01.1	172° 02′
Eighth	60+51.1	177° 31′
Ninth	60+01.1	179° 31′
Tenth	59+51.1 (P. C.)	180° 00′

As a check in taking deflections from the table, it should be noted that the first + ninth = second + eighth = third + seventh = fourth + sixth = 180 + $\Delta = 220° 00'$.

Example 2.

Given $\Delta = 20°20'$; P. I. at Sta. 37 + 18.2.
$T = 50.532$, $E = 4.5$ (Table II).

Suppose $T = 100 =$ approx. desired length of tangent.

Ratio $= \frac{100}{50.53} = 2$, say; hence $L = 200$, $T = 101.0$, $D = 10° 10'$.

P. I. $= 37 + 18.2$
T. $= 1 + 01.0$
P. C. $= 36 + 17.2$
L. $= 2$
P. T. $= 38 + 17.2$

$\frac{200}{10} = 20$. Use 40-foot chords applied five times.

Point.	Station.	Deflection.
P. T.	38+17.2	
Second	+77.2	Δ / 21° 40′
Fourth	37+37.2	35° 13′
Sixth	+97.2	165° 07′
Eighth	+57.2	178° 40′
Tenth (P. C.)	36+17.2	180° 00′

Second + eighth = fourth + sixth $= 200° 20'$. Check.

The quantities in Tables II and III are based on the definition that the "degree of curve" is the central angle subtended by an *arc* of 100 feet instead of a *chord* of 100 feet. The radius of a 1° curve is found by means of the following proportion:

$1° : 360° = 100$ feet: $2\pi R$ feet, hence

$$R = \frac{36{,}000}{2\pi} = \frac{36{,}000}{2(3.14159)} = 5{,}729.578.$$

The middle ordinate (M) of an arc whose central angle is $\alpha°$ and whose chord is c feet, is given by the formula:

$$M = R \text{ vers } \tfrac{1}{2}\alpha \qquad (4)$$

$$\text{Also } M = \frac{c^2}{8R} \text{ approx.} \qquad (5)$$

Formula (5) shows that for any radius the middle ordinates vary as the square of the chords. The above formulæ were used in computing Table III.

Assuming the arc to be parabolic, we have a convenient relation between ordinates at any point along the chord and the middle ordinate. (See fig. 3.) For example, an ordinate at eight-tenths of the chord-length from one end of the chord is six-tenths of the middle ordinate.

In practice, the middle ordinate is usually less than 1 foot, because the chords should not exceed the limit where they vary more than 0.05 foot from the arc. Table III shows these limits to be as follows:

100-foot chords up to 6° curves; middle ordinates up to 1.31 feet.
50-foot chords up to 16° curves; middle ordinates up to 0.87 foot.
40-foot chords up to 25° curves; middle ordinates up to 0.87 foot.
30-foot chords up to 37° curves; middle ordinates up to 0.72 foot.
25-foot chords up to 47° curves; middle ordinates up to 0.64 foot.
20-foot chords up to 67° curves; middle ordinates up to 0.58 foot.
15-foot chords up to 100° curves; middle ordinates up to 0.49 foot.

Suppose a 30° curve is to be used. Table III shows that 30-foot chords are about the longest advisable. However, if 50-foot points along the arc are desired, then the corresponding chords must be 49.87 feet.

THE "DEGREE OF CURVE"—A PLEA FOR THE ARC DEFINITION.

Books on railroad engineering define the "degree of curve" as the central angle subtended by a *chord* of 100 feet rather than an *arc* of 100 feet. The American Railway Engineering and Maintenance of Way Association indorsed this definition in 1907 by a vote which was not unanimous. The handbooks on highway engineering by Harger and Bonney and Blanchard define the "degree of curve" as the central angle of a 100-foot arc. The writer prefers this definition because it is more logical, simpler to use in practically all calculations, and involves no more work in the field.

The real difference between the two definitions is expressed by the formulae for the radii:

$$R_1 = \frac{50}{\sin \frac{1}{2}\Delta}, \text{ for "chord" definition.}$$

$$R_2 = \frac{5729.58}{D}, \text{ for "arc" definition.}$$

TABLE II.—*Externals, tangents, radii, and degrees of curve to a 100-foot circular arc.*

Δ	E.	Diff. 10′.	T.	Diff. 10′.	R.	D.	Deflection per foot.
°						°	
1	0.218	0.036	50.001	0.001	5,730	1	0.3
2	.436	.036	50.005	.001	2,865	2	.6
3	.655	.036	50.012	.001	1,910	3	.9
4	.873	.036	50.020	.002	1,432	4	1.2
5	1.092	.036	50.032	.002	1,146	5	1.5
6	1,310	.036	50.046	.003	955	6	1.8
7	1.530	.036	50.062	.003	818.6	7	2.1
8	1.749	.036	50.081	.004	716.2	8	2.4
9	1.969	.036	50.103	.004	636.6	9	2.7
10	2.189	.036	50.127	.005	573.0	10	3.0
11	2.409	.037	50.155	.005	520.9	11	3.3
12	2.630	.037	50.184	.005	477.5	12	3.6
13	2.851	.037	50.216	.006	440.8	13	3.9
14	3.073	.037	50.251	.006	409.3	14	4.2
15	3.296	.037	50.288	.007	382.0	15	4.5
16	3.519	.037	50.328	.007	358.1	16	4.8
17	3.743	.037	50.370	.008	337.0	17	5.1
18	3.968	.037	50.416	.008	318.3	18	5.4
19	4.193	.038	50.463	.009	301.6	19	5.7
20	4.419	.038	50.514	.009	286.5	20	6.0
21	4.646	.038	50.567	.010	272.9	21	6.3
22	4.875	.038	50.624	.010	260.4	22	6.6
23	5.104	.038	50.683	.010	249.1	23	6.9
24	5.334	.039	50.744	.011	238.8	24	7.2
25	5.565	.039	50.809	.011	239.2	25	7.5
26	5.797	.039	50.876	.012	220.4	26	7.8
27	6.030	.039	50.946	.012	212.2	27	8.1
28	6.264	.039	51.020	.013	204.6	28	8.4
29	6.500	.040	51.096	.013	197.6	29	8.7
30	6.737	.040	51.175	.014	191.0	30	9.0
31	6.976	.040	51.257	.014	184.8	31	9.3
32	7.216	.040	51.342	.015	179.1	32	9.6
33	7.457	.040	51.430	.015	173.6	33	9.9
34	7.700	.041	51.521	.016	168.5	34	10.2
35	7.944	.041	51.615	.016	163.7	35	10.5
36	8.190	.041	51.712	.017	159.2	36	10.8
37	8.438	.042	51.813	.017	154.9	37	11.1
38	8.688	.042	51.917	.018	150.8	38	11.4
39	8.939	.042	52.024	.019	146.9	39	11.7
40	9.193	.043	52.135	.019	143.2	40	12.0
41	9.448	.043	52.249	.020	139.8	41	12.3
42	9.706	.043	52.366	.020	136.4	42	12.6
43	9.965	.044	52.487	.021	133.3	43	12.9
44	10.227	.044	52.611	.021	130.2	44	13.2
45	10.491	.044	52.739	.022	127.3	45	13.5
46	10.757	.045	52.871	.023	124.6	46	13.8
47	11.025	.045	53.006	.023	121.9	47	14.1
48	11.296	.046	53.145	.024	119.4	48	14.4
49	11.570	.046	53.288	.025	117.0	49	14.7
50	11.846	.047	53.435	.025	114.6	50	15.0
51	12.125	.047	53.586	.026	112.3	51	15.3
52	12.407	.047	53.740	.027	110.2	52	15.6
53	12.691	.048	53.899	.027	108.1	53	15.9
54	12.979	.049	54.062	.028	106.1	54	16.2
55	13.270	.050	54.230	.029	104.1	55	16.5
56	13.564	.050	54.402	.029	102.1	56	16.8
57	13.861	.050	54.577	.030	100.5	57	17.1
58	14.161	.051	54.758	.031	98.79	58	17.4
59	14.465	.051	54.943	.032	97.11	59	17.7
60	14.773	.052	55.133	.033	95.49	60	18.0
61	15.084	.053	55.328	.033	93.93	61	18.3
62	15.399	.053	55.527	.034	92.41	62	18.6
63	15.718	.054	55.732	.035	90.95	63	18.9
64	16.041	.055	55.941	.036	89.52	64	19.2

This difference is almost negligible for very flat curves but quite appreciable for sharp curves.

If $D = 1°$, $R_1 = 5{,}729.65$ and $R_2 = 5{,}729.58$. These values of R_1 and R_2 are so nearly the same that tables giving the functions of a 1° curve apply to either definition, as is indicated by the following formulæ:

Tangent $= T = R \tan \frac{1}{2}\Delta = 5{,}729.6 \tan \frac{1}{2}\Delta$.

External $= E = R \operatorname{exsec} \frac{1}{2}\Delta = 5{,}729.6 \operatorname{exsec} \frac{1}{2}\Delta$.

Long chord $= 2R \sin \frac{1}{2}\Delta \quad 2 \times 5{,}729.6 \sin \frac{1}{2}\Delta$.

The formula for the actual length of curve: $L = 100 \times \frac{\Delta}{D}$ is absolutely exact according to the *arc* definition but only approximate for the *chord* definition, and departs too far from the truth for sharp curves.

To further illustrate the confusion caused by the *chord* definition, suppose $\Delta = 90°$ and a 40° curve is to be used. Here $R_1 = 146.19$ and $R_2 = 143.24$, a difference of practically 3 feet. Tangent length for 1° curve = 5,729.6 (Keith's Tables in back of field book). Tangent for 40° curve $= \frac{5{,}729.6}{40} = 143.2$. Nominal length of curve measured along 100-foot chords $= 100 \times \frac{\Delta}{D} = 100 \times \frac{90}{40} = 225$. The actual length of arc is 229.6 feet. Now, to make the tangents fit this arc, corrections must be added. In this case (for $\Delta = 90°$ and $D = 40°$), we find 2.94 in Table V of the field books.

Corrected tangent $= 143.22 + 2.94 = 146.2$. Suppose the station number of the P. C. is $37 + 00$, then the number of the P. T. is $3{,}700 + 225 = 39 + 25$. The P. T. stake is labeled the same as it would be according to the *arc* definition, but it is 2.94 feet farther along the tangent than it should be. Hence, if this is repeated 10 times, the road is recorded as 29.4 feet shorter than it really is.

If after the P. C. and P. T. are established with the correction added, the curve is laid out by starting the measurements at the P. C., using 25-foot chords (that is, chords which are practically equal to the corresponding arcs); then the distance of 225 feet will fall short of the P. T. by about 4.6 feet. The instrument man, unless he remembers the real meaning of the "correction," will wonder what is wrong and perhaps waste time trying to find the error.

The use of the "correction" implies 100-foot chords, but chords of such great length would not properly define a 40° curve. If shorter chords are used for sharper curves, so that the chords will closely approximate the arcs (see Table III), then "corrections" for the tangents and externals are unnecessary. This suggestion was made by A. M. Wellington years ago.

Many highway engineers still make use of the "chord of 100 feet" definition in dealing with curves, but they admit considerable difficulty in laying out short radius curves. The writer has formulæ and tables for two different special methods of locating sharp curves derived by highway engineers who still use the *chord* idea. These methods are clever but far from simple.

With the "arc of 100 feet" definition and shorter chords, there is absolutely no more difficulty in locating sharp curves than flat ones.

If highway engineers adopt the "arc" definition, then the tables in the back of field books No. 361 should be revised. Table V giving "corrections" for the tangents and externals is unnecessary and very confusing. Table VI giving deflections for subchords for short radius curves is inconsistent with the *arc* definition and hence it should be left out. Table III, giving radii, middle ordinates, etc., should be enlarged to include curves as sharp as 100° and revised to agree with the "arc of 100 feet" formulæ. Table IV, giving the tangents, externals, and long chords to a 1° curve, is the same for either definition.

TABLE III.

Degree curve.	Radius.	Middle ordinates. For chords of—					Chords. For arcs of—				
		100 feet.	80 feet.	60 feet.	50 feet.	40 feet.	100 feet.	80 feet.	60 feet.	50 feet.	40 feet.
°											
1	5,730	0.2	0.1	0.1	0.0	0.0	100	80	60	50	40
2	2,865	.4	.3	.2	.1	.1	100	80	60	50	40
3	1,910	.6	.4	.2	.2	.1	100	80	60	50	40
4	1,432	.9	.6	.3	.2	.1	100	80	60	50	40
5	1,146	1.1	.7	.4	.3	.2	100	80	60	50	40
6	955	1.3	.8	.5	.3	.2	100	80	60	50	40
7	818.6	1.5	1.0	.6	.4	.3	99.94	80	60	50	40
8	716.2	1.8	1.1	.6	.4	.3	99.92	80	60	50	40
9	636.6	2.0	1.2	.7	.5	.3	99.90	79.95	60	50	40
10	573.0	2.2	1.4	.8	.5	.3	99.88	79.93	60	50	40

Degree curve.	Radius.	Middle ordinates. For chords of—					Chords. For arcs of—				
		80 feet.	60 feet.	50 feet.	40 feet.	30 feet.	80 feet.	60 feet.	50 feet.	40 feet.	30 feet.
°											
11	520.9	1.5	0.9	0.6	0.4	2	79.92	60	50	40	30
12	477.5	1.7	.9	.7	.4	2	79.91	60	50	40	30
13	440.8	1.8	1.0	.7	.4	2	79.89	60	50	40	30
14	409.3	2.0	1.1	.8	.5	3	79.87	59.95	50	40	30
15	382.0	2.1	1.2	.8	.5	3	79.85	59.94	50	40	30
16	358.1	2.2	1.3	.9	.6	3	79.83	59.93	49.95	40	30
17	337.0	2.4	1.3	.9	.6	3	79.81	59.92	49.95	40	30

Degree curve.	Radius.	Middle ordinates. For chords of—					Chords. For arcs of—				
		60 feet.	50 feet.	40 feet.	30 feet.	25 feet.	60 feet.	50 feet.	40 feet.	30 feet.	25 feet.
°											
18	318.3	1.4	1.0	0.6	0.3	0.2	59.91	49.94	40	30	25
19	301.6	1.5	1.0	.7	.4	.3	59.90	49.94	40	30	25
20	286.5	1.6	1.1	.7	.4	.3	59.89	49.94	40	30	25
21	272.9	1.7	1.1	.7	.4	.3	59.88	49.93	40	30	25
22	260.4	1.7	1.2	.8	.4	.3	59.87	49.93	40	30	25
23	249.1	1.8	1.3	.8	.5	.3	59.84	49.91	40	30	25
24	238.8	1.9	1.3	.8	.5	.3	59.84	49.91	40	30	25
25	229.2	2.0	1.4	.9	.5	.3	59.82	49.90	39.95	30	25
26	220.4	2.0	1.4	.9	.5	.3	59.81	49.90	39.95	30	25
27	212.2	2.1	1.5	.9	.5	.4	59.79	49.89	39.94	30	25
28	204.6	2.2	1.5	1.0	.5	.4	59.78	49.88	39.94	30	25
29	197.6	2.3	1.6	1.0	.6	.4	59.77	49.87	39.93	30	25
30	191.0	2.3	1.6	1.0	.6	.4	59.76	49.87	39.93	30	25
31	184.8	2.4	1.7	1.1	.6	.4	59.74	49.85	39.92	30	25
32	179.1	2.5	1.7	1.1	.6	.4	59.73	49.84	39.92	30	25

Degree curve.	Radius.	Middle ordinates. For chords of—					Chords. For arcs of—				
		50 feet.	30 feet.	25 feet.	20 feet.	10 feet.	50 feet.	30 feet.	25 feet.	20 feet.	10 feet.
°											
33	173.6	1.8	0.6	0.4	0.3	0.1	49.83	30	25	20	10
34	168.5	1.8	.7	.5	.3	.1	49.82	30	25	20	10
35	163.7	1.9	.7	.5	.3	.1	49.81	30	25	20	10
36	159.2	2.0	.7	.5	.3	.1	49.80	30	25	20	10
37	154.9	2.0	.7	.5	.3	.1	49.79	29.95	25	20	10
38	150.8	2.1	.7	.5	.3	.1	49.78	29.95	25	20	10
39	146.9	2.1	.8	.5	.3	.1	49.77	29.95	25	20	10
40	143.2	2.2	.8	.5	.3	.1	49.75	29.94	25	20	10
41	139.8	2.2	.8	.6	.4	.1	49.74	29.94	25	20	10
42	136.4	2.3	.8	.6	.4	.1	49.73	29.94	25	20	10
43	133.3	2.3	.8	.6	.4	.1	49.71	29.93	25	20	10
44	130.2	2.4	.9	.6	.4	.1	49.69	29.93	25	20	10
45	127.3	2.4	.9	.6	.4	.1	49.67	29.92	25	20	10
46	124.6	2.5	.9	.6	.4	.1	49.65	29.92	25	20	10
47	121.9	2.6	.9	.6	.4	.1	49.63	29.92	24.95	20	10
48	119.4	2.6	.9	.6	.4	.1	49.62	29.92	24.95	20	10
49	117.0	2.7	1.0	.7	.4	.1	49.60	29.91	24.95	20	10
50	114.6	2.7	1.0	.7	.4	.1	49.59	29.91	24.94	20	10

BELGIAN TRAFFIC CENSUS REPORT ISSUED AFTER LONG DELAY BY WAR

COPIES of a report issued this year by the Belgian Ministry of Public Works, administration of bridges and roads, dealing with a census of traffic on all the roads of the Kingdom in 1908, have recently been received in this country.

The preparation of the report has long been delayed by the war. In fact, some of the most valuable records were destroyed by the Germans during the occupation. The figures representing the extent of the traffic on the various roads are now, of course, of little value; but the description which accompanies the report, of the purpose of the census and the methods adopted in conducting it, will interest engineers in this country who believe that the time is ripe for a similar comprehensive survey of American roads.

PURPOSES OF THE CENSUS.

The census was conducted primarily to supply accurate data upon which to base a classification of the roads of the Kingdom. It was the intention to use the data to classify all roads among the three categories as follows:

1. Roads of the first importance by reason of the intensity of their traffic, their direction, width, and state of improvement.
2. Roads of much less importance in the above respects, ranking comparatively with ordinary country roads.
3. Roads intermediate between the preceding in importance.

It was also a matter of importance to the adminstration of bridges and roads to possess an authentic basis for a correct apportionment of appropriations for construction and maintenance, according to the importance of the several roads.

METHODS ADOPTED FOR THE CENSUS.

The census was taken on 24 days between March 10 and December 18, distributed in such a way as to represent variations in traffic due to the seasons and the days of the week. In some places supplementary counts were made on market days and days of fairs, pilgrimage, noted processions, etc. The counting began on the regular days at 8 a. m. and ended at the same hour the next morning.

The counting was intrusted to the road men (cantonniers) and some of the laborers under the direction of the inspectors (conducteurs) of bridges and roads, the number and location of the stations being previously determined by the division engineers.

The cantonniers kept a record of every vehicle which passed the observation points, on a special tabular form, recording for each vehicle its method of propulsion, the number of wheels, the width of tires, the kind of cargo carried, the number of passengers, and the weight of the load.

The weight of the load was obtained at some of the stations by means of platform scales, the location of these scales influencing the selection of the points. At other points, where there were no scales, the weight of the load was estimated by measuring the cubic contents of the load and later multiplying by the unit weight of each commodity as taken from standard tables of unit weights. Frequently the weight of the load was found written upon the boxes or containers in which it was carried. This particularly was the case with goods being carried to or from railroad freight stations.

The report states that the cantonniers found no difficulty in performing their work, that the public gave them the information desired with very good grace, and that no special police measures were required.

At the end of each day's counting the reports of the cantonniers were transmitted to supervising officials, known as the conducteurs, who condensed the data and recorded in another table the total number of each kind of vehicle and the total weight of the loads passing the several points. The provincial chief engineers verified these tables and transmitted them to the Ministry of Public Works.

At the central administration the results of the counts for the 24 days were summarized and the mean totals for the day and the year were determined.

In estimating the weight of vehicles predetermined average weights for each class of vehicles were used by all officials. Thus for automobiles the weight used was 3,970 pounds, which was supposed to include the weight of three passengers. Motorcycles were assumed to weigh 198 pounds, the cyclist 154 pounds; consequently each motorcycle was counted as 352 pounds. No account was taken of the weight of bicycles, nor of the weight of horses, or cattle as these were assumed to cause no appreciable wear of the road surface.

On the basis of the statistical information acquired, two maps were prepared, the first showing by the width of the lines indicating the roads the total annual tonnage transported over each road, and the other in a similar manner the number of automobiles, motorcycles, and bicycles passing each point on the roads annually. These diagram maps unfortunately disappeared during the occupation.

RESULTS OF THE CENSUS.

Taking into consideration with the traffic figures the costs of maintaining the roads, and comparing these figures with similar data for the year 1897, it is shown that the cost of maintenance has not increased proportionately to the volume and weight of traffic.

The traffic data for the two years indicate an enormous increase in traffic in the intervening period. But for purposes of comparing the importance of the various roads the Ministry believes that the data are not entirely satisfactory. Thus a given road in one section, though very important for the neighborhood through which it passes, may have an average traffic much below that of a road serving neighborhoods of much less account in another section. The same road at various points between its extremities was found to present enormous variations of traffic.

These facts confirm the necessity of considering the general direction and economic surroundings of the roads as well as the actual observed traffic for purposes of classification.

IMPROVEMENTS SUGGESTED BY ENGINEERS.

As a result of the experience gained in taking this census the Ministry believes that future efforts should take into account the character and condition of the roads at the time the counts are made, and also the state of the weather. Roads in bad condition or temporarily blocked by construction work in progress may be shown to have less importance than they actually possess unless these facts are taken into account. Bad weather in one section and good weather in another may also influence the classification unfairly unless the weather conditions are considered.

To reduce the expense of future counts and the time consumed in making them, the Ministry believes that the classification of different kinds of loads may be omitted. After all what it is important to know is the gross weight carried over the roads. Another saving might be made, in the opinion of the Ministry, by leaving out of the counting those roads whose traffic is known beforehand to be very light. Still another way of reducing expense would be to confine the counting on all but two or three of the days to the daylight hours, or possibly from 6 a. m. to 8 p. m. To the daytime results could be added the average results of the two or three night counts, and the accuracy and utility of the combined results would not be materially affected.

A NEW CONCRETE ROAD FILM.

The motion-picture laboratory of the Department of Agriculture has recently completed a new motion-picture film of concrete road construction.

The title of the picture is "Modern Concrete Road Construction." The scenario was written by and the photography was directed by engineers of the Bureau of Public Roads. The photographs were taken in Delaware and New Jersey, with the cooperation of the two State highway departments.

Every process involved in the construction of a concrete road is shown in the film, from the heavy grading to the completed road. The picture opens with a view of an automobile stuck in the mud of an unimproved country road. This scene carries the caption "If your roads are like this," and it is followed immediately by a view of a fine concrete highway with the caption completing the question, "why not work for roads like this?"

The methods of constructing such a road are then shown in regular order on the screen. Methods used in light and heavy grading are depicted by wheel-scraper gangs and steam-shovel outfits served by motor trucks, which dash up to the shovel and are off to the dump in incredibly short time. Under the caption "Monster machines are used by modern contractors to rip up old pavements and make light cuts," one scene shows an old macadam road being torn up, the stone screened and loaded into wagons by one modern machine.

The picture continues with views of fine grading and form setting, pictures showing the quarrying of rock for aggregate and the means of handling material at the freight siding, and the conveyance from storage bins to the roadside by industrial railway.

At the site of the work the bodies of the industrial railway cars are lifted from the trucks and the contents dumped into the mixer, and the picture then shows the details of the various processes of depositing and finishing the road, including hand striking, tamping, rolling, and belting; and by way of contrast, another scene shows a mechanical tamper in operation.

After showing the methods of curing and the trimming of shoulders, several views of completed road are flashed upon the screen, and the picture closes with a thrilling race between a Pennsylvania Railroad train and a motor truck on a concrete highway.

The picture will be loaned to interested persons who make application for use at "good roads meetings," schools, colleges, and meetings of engineers.

——BUY W. S. S.——

The sailors on the 25 vessels of the United States Navy now stationed at the Portsmouth (N. H.) Navy Yard, are the busy little savers. They have discovered that if they put their spare change into war savings stamps and thrift stamps, they can cease to worry about the safety of their coin. If the stamps are registered they are proof against loss, fire, or destruction. If the gob is transferred suddenly, he does not have to worry about transferring his account from one bank to another, for he can either buy or redeem his stamps at any postoffice.

——BUY W. S. S.——

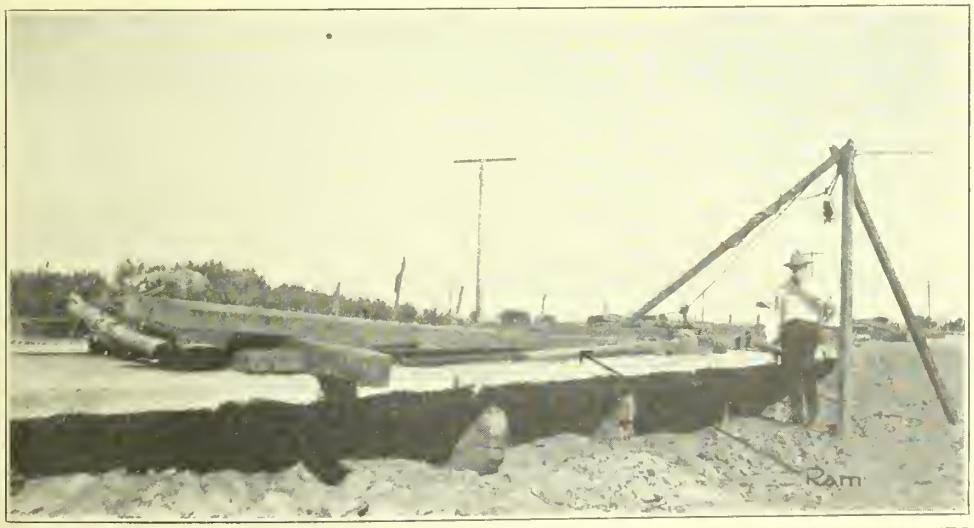
CONCRETE ROAD SLABS UNDAMAGED BY WASHOUT OF SANDY SUBGRADE

A REPORT received at the Bureau of Public Roads recently contains an interesting description of damage done by high water to the sand shoulders of a section of concrete on the Camino Real near Las Cruces, N. Mex. More interesting than the damage itself is the description of the methods which were adopted by the district engineer for the State highway department, which resulted in saving the road from very serious damage.

ON ACCOUNT OF THE HIGH SHOULDERS, WATER FLOWED ALONG THE CONCRETE UNTIL A SUFFICIENT AMOUNT COLLECTED TO OVERFLOW INTO THE SIDE DITCHES.

The road is a Federal-aid project, known as New Mexico No. 15. The project begins 1 mile south of Mesquite and runs northward 11.68 miles to Las Cruces. The concrete surface is 16 feet wide and has an average depth of 6 inches; the cost of construction is estimated at slightly less than $30,000 a mile.

The soil which forms the subgrade and the shoulders is generally sandy, and in many places the shoulders are of soft blow sand which will not pack. This condition had previously given trouble to automobilists using the road. The loose sand is too soft to hold the weight of an automobile, and if a car, driven at high speed, is turned off the surfaced section there is apt to be trouble. In one stretch a half mile in length seven such accidents are known to have occurred since the opening of the road.



THE SLABS WERE JACKED UP AND CRIBBED IN PLACE AND WET SAND WAS RAMMED INTO THE WASHED-OUT SUBGRADE.

The washouts which occurred in these sandy shoulders as a result of the heavy storm which came during August were not entirely unanticipated. The Bureau of Public Roads had called attention to the probability that such damage would be inflicted by heavy rains nearly a month before. But it is doubtful whether the injury could have been avoided entirely by any amount of foresight.

The most serious damage was done by the unusually large volume of water which reached the sandy side ditches. The water completely demolished the shoulders in many places and undercut the surface to a maximum depth of 11 feet. The origin of the heavy flow of water is not definitely known at this time. An investigation is being made to discover the cause of it, but apparently it did not result from the drainage of the road alone, and it is probable that future damage from the same cause can only be averted by a purchase of rights of way and an alteration of natural water-courses several miles from the project.

In part, however, the damage was due to the fact that the shoulders had not been trimmed, and that the water which drained from the road itself could not reach the ditches directly, but was forced by the high shoulders to run along the edge of the concrete until

[Concluded on page 25.]

9,630 MILES OF MARKED TRAILS TO BE BUILT WITH FEDERAL AID

UP TO September 30, 1920, Federal aid had been approved for the construction of 855 projects, which form links in one or the other of the 24 marked trails which have been laid out by private associations to cross the country from East to West and North to South.

The mileage which will be constructed with Federal aid on each of the several trails is shown in the following table:

MILEAGE OF APPROVED FEDERAL AID PROJECTS ON VARIOUS NATIONAL TRAILS AS OF SEPT. 30, 1920.

	Length Federal aid approved projects miles.
Dixie Highway	895
Ozark Trails	294
Yellowstone Trail	455
Meridian Highway	677
Bankhead Highway	963
National Old Trails	826
King of Trails	474
National Parks Highway	647
Theo. Roosevelt International Highway	425
Jefferson Highway	604
Lincoln Highway	766
Old Spanish Trail	516
Mississippi Valley Highway	237
Dixie Overland Highway	259
Jackson Highway	161
Pacific Highway	183
Roosevelt National Highway	314
Colorado to Gulf	22
Pikes Peak Ocean to Ocean	319
Atlantic Highway	140
Miscellaneous	452
Total	9,630

The extent to which Federal aid has been applied to the trails varies in the different States. Quite naturally the Western States are using much more of their Federal apportionments in developing roads of this character than the Eastern States. This is due to the fact that the routes in the Eastern States had already been improved to a large extent before the roads were selected by the pathfinders. This was not true in the West, where long stretches of the selected roads were still in an unimproved condition when they were designated.

Nevada leads in its use of Federal funds on roads of this character. Eighty-three per cent of its entire mileage of approved Federal-aid roads lies on one or the other of the trails which cross the States. On these roads Nevada will spend 90 per cent of the Federal money which has been granted to her.

Indiana is a close second, with 80 per cent of its entire Federal-aid mileage and 83 per cent of its money aid applied to the construction of the trails; and Oklahoma, with 76 per cent of its mileage and 81 per cent of its Federal funds, is not far behind.

Florida takes the lead in the percentage of its funds which will be used for trail building, with 94 per cent of its Federal allotments so applied; but this amount will be spent for only 56 per cent of the mileage which has been approved in the State.

In addition to the above, the States of Illinois, Kansas, Montana, New Mexico, Utah, and Washington are each using 50 per cent or more of their Federal money for the upbuilding of the trails.

The average expenditure on these roads of 35 per cent of the Federal money allotted to all the States would be greatly increased by the exclusion of such States as Connecticut, Delaware, Maine, Massachusetts, New Hampshire, Vermont, and West Virginia, which are either not traversed by any of the trails or have a very limited mileage within their borders. It would be further increased by eliminating such States as New Jersey, New York, and Pennsylvania, in which the selected routes have been improved in large measure by the States.

In presenting this analysis it is recognized that the system of trails does not constitute an entirely satisfactory system of transcontinental roads. Their selection in many cases has been influenced by such factors as preexisting improvement, promises of improvement by local communities in return for the designation of the route through the community, and pressure of selfish influences leading to the diversion of the route from the ideal location. In general, also, too much weight has been given to the desirability of touching points of historic and scenic interest. The Bureau of Public Roads believes that there are many sections of Federal-aid roads which do not fall on any of the designated trails which will serve to better advantage as sections of a truly national system of roads than the parallel sections of the trails.

In cooperation with the advisory committee of State highway officials the bureau is perfecting plans for a classification of the highways of the country through the coordinate efforts of the several States and the Federal Government. This classification, when it is completed, will rate the millions of miles of roads in the country, for the first time, in the order of their importance, from the national, State, and local standpoints. It is the intention of the departments that it will serve as the basis of all future construction; and it will greatly simplify operations under the Federal-aid act in that, for the first time, it will present a reliable measure of the relative importance of the roads of the country.

THE EFFECT OF ALKALI UPON CONCRETE

By S. H. McCRORY, Chief of Drainage Investigations, Bureau of Public Roads.

THE attention of engineers has been drawn recently to a number of cases in which concrete structures have partially or totally failed, due to the action of alkali upon the concrete. The extent and severity of this action has caused considerable concern among engineers intrusted with the design or construction of concrete structures in regions where the soils and ground waters are alkaline. Such conditions generally are found in the arid and semiarid regions of the United States. Recently, however, a number of failures of concrete drain tile exposed to the action of alkaline soils and ground waters have occurred in the southwestern part of Minnesota. The mean annual rainfall in this region varies from 25 to 30 inches per annum and yet strong concentrations of alkalies are found.

The alkalis present in the soils are the salts of various metals. The more common are sodium chloride (NaCl), sodium sulphate (Na_2SO_4), magnesium sulphate ($MgSO_4$), calcium sulphate ($CaSO_4$), calcium carbonate ($CaCO_3$), and calcium bicarbonate ($Ca(HCO_3)$) Other salts are also frequently present. Typical analyses of alkalis from the surface of the ground in various locations are shown in Table No. 1, which is taken from Technological Paper No. 95, Bureau of Standards.

TABLE NO. 1.—*Typical analyses of alkalis from various localities.*

Location.	Composition of soluble solids in per cent.					
	Na.	K.	Ca.	Mg.	Cl.	SO_4.
Garland, Wyo.	30.8	0.5	0.6	0.1	Trace.	68.0
Fort Shaw, Mont.	26.2	.2	2.3	1.1	1.1	69.1
Sunnyside, Wash.	23.9	.2	.6	.6	10.0	64.7
Yuma, Ariz.	24.7	.5	7.1	.....	52.6	15.1
Roswell, N. Mex.	10.8	2.3	16.8	4.9	22.0	43.2
Montrose, Colo.	9.4	.....	2.1	26.7	Trace.	61.8
Grand Junction, Colo.	28.1	.....	.7	6.6	17.1	47.5
Huntington, Utah.	27.6	.6	2.4	2.5	.1	66.8

In Table No. 2 are presented a number of analyses of drain and soil water from various locations:

TABLE NO. 2.—*Analyses of drain and soil water from various localities*

Location.	Per cent soluble solids in water.	Percentage reacting values.							
		Na.	Ca.	Mg.	Cl.	SO_4.	CO_3.	NO_3.	HCO_3.
Garland, Wyo.	0.33	32.0	19.3	7.7	3.2	40.6	6.2	.....	.....
Fort Shaw, Mont.	.20	30.6	6.6	12.8	1.6	34.2	14.2	.....	.....
Sunnyside, Wash.	.40	24.7	14.0	11.3	6.1	38.1	5.8	.....	.....
Yuma, Ariz.	.11	23.5	16.3	10.2	15.4	12.9	21.7	.....	.....
Roswell, N. Mex.	.46	23.9	19.4	6.7	27.1	20.0	2.9	.....	.....
Montrose, Colo.	.50	9.2	15.8	25.0	.5	46.0	3.5	.....	.....
Grand Junction, Colo.	.85	25.9	10.1	14.0	17.7	28.7	1.9	1.7	.....
Huntington, Utah.	.30	18.3	20.1	11.6	1.8	40.8	7.4	.....	.....
Lyon County, Minn.	.28	3.5	22.2	24.3	.3	47.5	.2	.....	1.9
Lyon County, Minn.[1]	3.06	25.9	8.6	15.5	T.	49.5	.1	T.	.4

[1] Soil water.

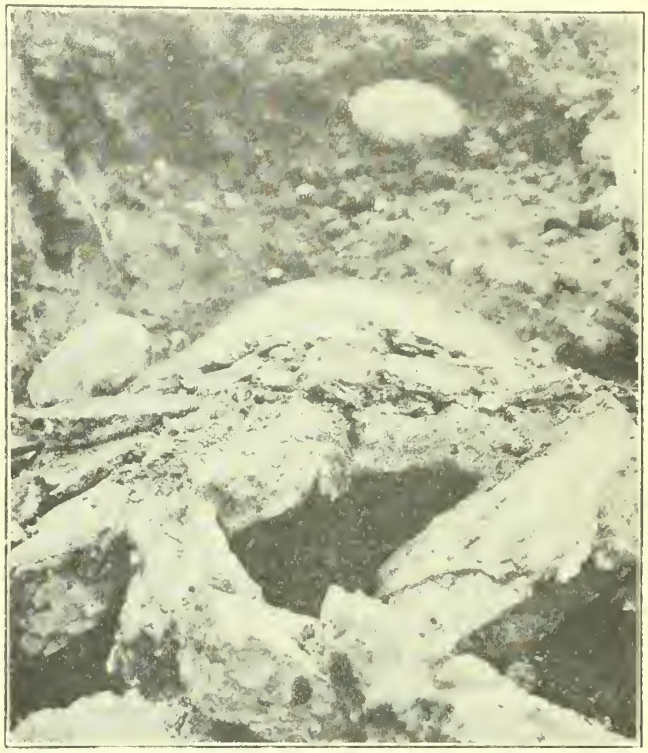


FIG. 1.—TWENTY-FOUR INCH CONCRETE TILE WHICH HAS ALMOST COMPLETELY DISINTEGRATED. THIS TILE WAS PLACED AT SUCH A DEPTH THAT IT WAS NEVER SUBJECTED TO FREEZING AND THAWING.

In both tables the SO_4 content is high for all localities except Yuma and Roswell. The alkali at Roswell, though low in SO_4, nevertheless causes serious injury to concrete that is exposed to it. It will be noted in these tables that usually some one of the constituents will predominate in a given section. Along the seacoast the predominating salt is usually sodium Chloride (NaCl) or common salt, while in the Great Plains regions the sulphate type predominates.

THE ACTION OF THE ALKALI.

When concrete is exposed to the action of solutions of these salts the lime of the cement combines with the salts to form other compounds. The chemical action is accompanied by a change in the physical condition of the concrete. The first indication of the action of the alkali that can be noted is the presence of minute crystals of various salts in the concrete. These can be detected if fresh fractures are examined. As the action progresses a chalky band forms in the concrete near the surface which is in contact with the soil. In drain tile this band usually forms at first about three-eighths of an inch beneath the outer surface. As the action progresses the band widens and assumes a white chalky appearance, much like lime

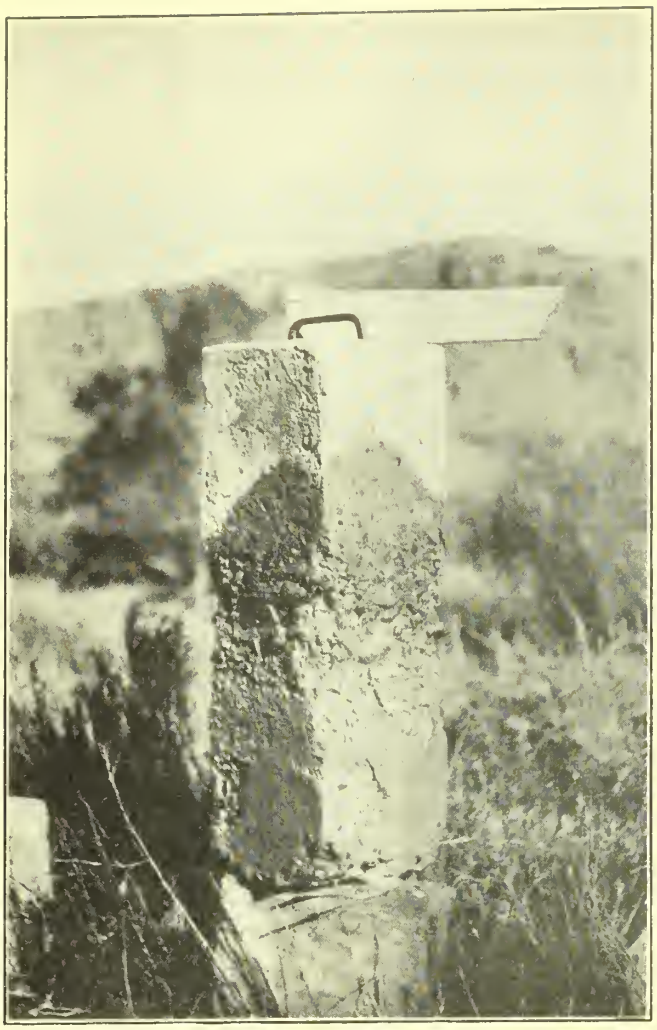


FIG. 2.—CONCRETE BLOCK 1–2½–5 CONCRETE THAT HAS BEEN EXPOSED TO THE ACTION OF STRONG ALKALINE WATERS FOR ABOUT 4 YEARS.

mortar. As this chalky band widens, swelling and cracking of the concrete becomes apparent. One of the illustrations shows a 24-inch concrete tile which had been placed in an 11-foot cut and exposed for about four years to the action of soil water containing 2.22 per cent of alkali, of which 49 per cent was SO_4. The swelling and cracking is very noticeable in this instance. The other picture illustrates the typical action of alkali upon mass concrete, in this instance a concrete block which had been exposed to the action of the weather and alkalis for about four years.

Most concrete structures are alternately dry and wet. The alternate drying and wetting has a tendency to impair the concrete. When salts are present this deterioration is intensified, due to their crystallizing in the concrete when it dries. In most localities there is added to this action the disrupting effect caused by alternate freezing and thawing of the moisture in the concrete. While the effect of each of these factors on the concrete may be relatively very small, they combine to make the concrete more porous and thus to admit more readily the salt-bearing solutions to intimate contact with the cementing material. Some experimentors have thought that the disintegration of concrete was caused by the formation of substances having a large molecular volume and that this occurs when the sulphate salts of magnesium and sodium are present. The chemical reactions which take place are not fully understood, but it seems that failure is due to chemical rather than physical action.

A number of samples of concrete that have been subjected to the action of strong solutions of sulphates have been examined, and in each case it is found that a considerable amount of the cement has been removed. Microscopic examinations indicate that the cementing material has been replaced by other compounds of little cementing value, such as gypsum and the carbonates of lime and magnesia.

NO PROOF AGAINST ALKALI FOUND.

Many investigators have tried to find a method of making concrete that would be proof against the action of salts, but so far none has been successful. It has been shown, however, that the more impermeable the concrete, the more strongly resistant it is to the action of the salts. The strength of concrete does not seem to have a definite relation to the action of salts upon it as frequently, in testing concrete tile, specimens are found in which the concrete is seriously disintegrated but which shows little loss of strength when tested. In general, it may be said that all available data indicate that in sulphate waters the extent and rapidity of failure depend upon the concentration of the salts in the soil and soil water to which the concrete is exposed. Concentrations may occur which will cause the disintegration of the most impermeable concrete that can be made by methods now employed. Various experiments and investigations indicate however, that when exposed to solutions of equal strength the richest mix will prove most resistant. Concretes with high absorbtion are especially susceptible to attack.

TO SECURE MOST IMPERMEABLE CONCRETE.

If it is known that concrete is to be exposed to the action of alkalis, great care should be used in grading the materials so as to secure the densest and most impermeable concrete possible. If a choice is possible, the sand and coarse aggregate should be of such a character that they will not be affected by the action of the salts. Limestones, dolomites, and sandstones should be avoided. In placing the concrete great care should be exercised to secure the best possible workmanship. The concrete, after being placed in the forms, should be well spaded and tamped, and extra precautions should be taken to prevent the formation of a porous layer at the close of each day's work. The foundation should, if possible, be thoroughly drained either by

open ditches or underdrains. If this can not be done, it might be helpful to make the back fill next to the concrete of coarse gravel so that when the water table drops, capillary action will not bring moisture to the concrete through the soil. When it is necessary to use sand, gravel, or other aggregates that are known to cantain alkali salts in considerable amounts, they should be thoroughly washed before they are placed in the concrete, even if alkaline water has to be used.

Various preparations have been used in an attempt to make concrete impervious to moisture. Cement grout, tar coating, ferrous sulphate, and various waterproofing paints have been tried, but so far none of these seems to have been successful. Any value they have is of a temporary character. The use of intregal waterproofing compounds or hydrated lime might be of value in securing a more impermeable concrete.

Where high concentrations of salts are known to exist, the importance of careful grading and rich mixture, so as to secure the densest and most impermeable concrete possible, can not be overestimated. Under such conditions cement, sand, aggregate, and mixing water should be the best obtainable. The fabrication of the concrete should be done by experienced workmen, and when it is placed in the forms it should be done in such manner that the structure will be truly monolithic. The foundation should be provided with the best drainage obtainable. If these precautions are followed structures can be built which will be strongly resistant to the action of alkali. There is no assurance, however, that concrete of even the highest impermeability that can be obtained under present methods of manufacture will withstand the stronger concentrations of alkali of the sulphate type.

AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS TO MEET AT WASHINGTON

The annual meeting of the American Association of State Highway officials will be held this year at Washington, D. C., from the 13th to the 16th of December, inclusive. The headquarters will be at the Washington Hotel, at which the general meetings will be held. As the hotel is only one block from the Bureau of Public Roads, the bureau's building will be conveniently situated for committee meetings.

At the time this goes to press the program has not been definitely arranged. One of the subjects which is certain to be included, and which is expected to develop a lively discussion, is the problem of rail transportation. This question will be discussed from both viewpoints, those of the States and the railroads, with Mr. Daniel Willard, president of the Baltimore & Ohio Railroad, speaking for the railroads.

Among the other important topics which will probably be discussed are:

Load limitations for primary and secondary highways.

Failures of highways and the reasons therefor.

The treatment of subgrades and foundations.

The relative service value of different types of pavements.

State operation of cement plants.

One afternoon will be devoted to a visit to the experimental laboratory of the Bureau of Public Roads, at Arlington, Va., where the visitors will be given an opportunity to inspect the important impact, wear, and subgrade tests which are being conducted by the bureau.

As an additional attraction the bureau will provide transportation to enable the visitors to inspect the experimental roads which have been constructed in the vicinity of the city.

CONCRETE ROAD SLABS UNDAMAGED BY WASHOUT OF SANDY SUBGRADE

[Concluded from page 21.]

a sufficient amount had collected to overflow into the ditches. Deep cuts, in the fills particularly, were due to this cause.

Before the traffic could be stopped some of the slabs had settled, and the loss of large sections of the surface was narrowly averted. The prompt and intelligent action of the State's district engineer prevented the collapse of large sections of the pavement; but the fact that not a single crack or flaw developed in any slab is a tribute to the excellent workmanship and material employed in the construction of the road.

Until the damage could be repaired the washed shoulders were covered with brush to prevent further erosion in the event of another storm, and as rapidly as possible the undercut gaps in the subgrade were refilled and consolidated. Where it was found that the slabs had sagged out of line wooden stringers were placed under them near the outer edge, and the concrete was raised to the proper grade by means of hand jacks bearing on the stringers.

Once the slabs were raised into true position cribbing was placed under the stringers and the jacks were removed. The sand was then replaced under the slabs, previously wetting it to make it possible to consolidate it. The consolidation was effected by means of a heavy ram, shown in one of the illustrations, which was suspended from a tripod and operated by three or four men.

The shoulders when repaired were not solid enough to support traffic, and posts were set, therefore, along the edge of the concrete to prevent their use, but the concrete surface was opened to traffic at once and is carrying the weight of vehicles without sign of failure. The results of the treatment appear to be excellent in every respect, and no settling is anticipated.

OUTLINE OF THE FIELD TO BE COVERED BY HIGHWAY RESEARCH

By A. N. JOHNSON, Dean of College of Engineering, University of Maryland.

THE need for highway research is becoming more and more apparent as our highway program develops. At the recent convention of land-grant colleges held at Springfield, Mass., the subject of highway research was discussed by Mr. Thomas H. MacDonald, Chief of the United States Bureau of Public Roads, who pointed out that one of the largest fields in engineering endeavor during the next 25 years will be the development of our highways and highway transportation. We can not too soon begin these investigations, the results of which should be at hand if economical and scientific progress is to be insured and the largest return made to the public, which has provided so abundantly the funds for this great undertaking. In the discussions before various engineering and technical bodies the lack of needful data by which intelligently to plan and build our highways has repeatedly been remarked.

It is unnecessary to develop further the argument for the need of highway research. Time and space will be more profitably employed in the discussion of highway research itself. It seems proper, therefore, at first to present a general outline of the field to be covered, as a survey of this field should prove helpful. An attempt has therefore been made to present such an outline, which was prepared in September, at the suggestion of Mr. MacDonald, by Charles J. Tilden, professor of engineering mechanics at Yale University, A. T. Goldbeck, testing engineer of the United States Bureau of Roads, and the writer.

The arrangement, as well as the subjects themselves, as here presented for investigation, should be considered more as a general view of the field, rather than a work program. Three general divisions have been named: (1) Investigations affecting road construction and maintenance or road design; (2) investigations affecting the economics of road operation or the use of the road; (3) investigations affecting the economic value of highways to a community.

Under each of these headings are listed the principal factors involved. In turn, a number of subjects have been named as suggestive of those to be included under the various factor headings.

As various work programs are developed and data accumulated a comprehensive outline becomes useful as a guide to disclose whether the work programs are balanced, and if not, to point to those subjects about which more information should be gathered.

The data that may be developed by a given work program, it is evident, may be useful from a number of viewpoints. Thus a traffic study may furnish not only information as to the weights or loads for which to design our highways, it may serve also as an index of the economic value of the roads, and it may also be taken as a basis from which to determine operation costs. In fact, it may be remarked that traffic data underlie much of the information needed to plan and expend wisely for highway improvements.

Little further explanation of the analysis of the highway research field here presented is thought necessary other than to point out that it is to be regarded as tentative. As more study is given to the subject it doubtless will be possible in the near future to present a considerably more detailed outline which will be of greater assistance in outlining work programs.

A TENTATIVE OUTLINE FOR A COMPREHENSIVE PROGRAM OF INVESTIGATION OF PROBLEMS RELATING TO THE DESIGN, OPERATION, AND ECONOMIC VALUE OF HIGHWAYS.

Investigations of the effect on road construction and maintenance of:

1. Physical geographic conditions—
   - Climate.
   - Topography.
   - Geology.
2. Subgrade—
   - Character of soil.
   - Moisture.
   - Preparation.
3. Shoulders—
   - Width.
   - Character.
   - Roadside vegetation, trees, etc.
4. Drainage—
   - Bridges, culverts, etc.
5. Type of pavement—
   - Materials.
   - Construction methods.
6. Loads imposed by traffic—
   - Total weight of vehicle.
   - Distribution of weight—
     - On wheels.
     - Sprung and unsprung.
   - Tires.
   - Speed.
   - Wear.
7. Density of traffic—
   - Width of pavement.

Investigations of the effect on the economics of road operation of:

1. Road planning—
   - Financing.
   - Environment—
     - Farms.
     - Mines.
     - Timber lands.
     - Manufacturing centers.
   - Other transportation systems—
     - Railways.
     - Ocean, rivers, canals.
     - Airplane terminals.
   - Roadside treatment.
2. Grade.
3. Surface.
4. Alignment.
5. Traffic movement—
   - Regulations.
   - Grade separations.
6. Highway transport—
   - Vehicles—
     - Weights.
     - Number of units.
   - Routing.
   - Terminals.
   - Financing.
7. Franchises—
   - Street railways—
     - Motor, freight and bus lines.
   - Pipe lines.
   - Conduits.
   - Telegraph and telephone.

Investigations of the effect on the economic value of highways to a community of:

1. Highway traffic—
   - Distribution of traffic—
     - Geographical—
       - Relation to environment.
     - Seasonal—
       - Time of year.
     - Daily—
       - Day of week and month.
     - Hourly—
       - Hourly variation.
   - Character of traffic—
     - Passenger—(Horse drawn; Motor) } Weights per vehicle; per wheel; per inch of tread.
     - Freight—(Horse drawn; Motor) } Weights per vehicle; per wheel; per inch of tread.
   - Relation to other transportation systems—
     - Rail.
     - Water.
     - Air.
2. Highway costs—
   - Construction costs.
   - Maintenance costs.
   - Operation costs.
3. Financing highway improvements—
   - Methods—
     - Direct taxation.
     - Bond issues.
     - Vehicle taxes and licenses.
     - Tolls.
   - Distribution of cost—
     - To Federal Government—
       - State.
       - County.
       - Local subdivisions.
       - Property owner.

MODIFIED TNT AS A BLASTING EXPLOSIVE

By CHARLES E. MUNROE, Chief Explosives Chemist, and SPENCER P. HOWELL, Explosives Engineer, U. S. Bureau of Mines.

AMONG the surplus explosives left on hand with the War Department was a quantity of that styled Trojan grenade powder, which was especially designed during the war for use as a bursting charge in grenades and for which naturally there would be very little military use in time of peace. With a view to its disposal through use in civil projects a quantity was sent to the Bureau of Mines explosives experiment station, where analysis showed that its characteristic explosive ingredient was nitrostarch and that the powder had the following composition:

TROJAN GRENADE POWDER.

	Per cent.
Moisture	0.71
Nitrostarch	24.37
Oils	1.13
Sodium nitrate	37.62
Ammonium nitrate	33.34
Ammonium chloride	.39
Carbon and ash	2.44
	100.00

Trojan grenade powder appears as a dark-gray granular substance, part of which is slightly pulverulent. The granules are fairly hard. The explosive is not at all dusty, and has the consistency of granulated sugar.

NITROSTARCH.

Nitrostarch is a substance produced by treating starch with nitric and sulphuric acids and in appearance it looks very little different from powdered starch. It resembles nitrocellulose and nitroglycerin in its constitution and explosive properties and has been known longer than either, inasmuch as it was prepared by Braconnet in 1833. Nitrostarch explosives have in recent years been developed for industrial use in this country; they were used to a certain extent in blasting in the Canal Zone, yet as this grenade powder was a special composition it seemed desirable that a complete series of tests should be run upon it. This was done, and the results are reported in the following table in comparison with those previously obtained in testing ammonia dynamite.

Mr. J. E. Crawshaw (explosives testing engineer, United States Bureau of Mines) in reporting these results says:

"It will be noted that the physical characteristics of these two explosives are almost the same. Accordingly, Trojan grenade powder would be specially suited for the type of work for which 40 per cent ammonia dynamite is now used, i. e., quarrying and tunneling in moderately hard rock, road building, excavations, and stump blasting.

"Particular attention is called to the hygroscopic properties of this explosive. As Trojan grenade powder shows a very marked tendency to absorb moisture, it can only be used in dry work, stored in dry places, and used in dry weather. All boxes of this explosive received at the Pittsburg Experiment Station of the Bureau of Mines showed evidence of moisture absorption, and two of the boxes to such an extent that the contents had to be destroyed shortly after their receipt. It is very probable that on examination of this material in storage, many other boxes will be found in very poor condition.

Results of tests of Trojan grenade powder and ammonia dynamite.

Explosive.	Rate of detonation (motors per second).	Trauzl lead block (cubic centimeters)	Small lead block (millimeters).	Pressure (kilograms per square centimeter).	Unit deflective charge (grams).	Calorimeter (calories per kilogram).	Volume of gas (liters).
40 per cent ammonia dynamite	3,157	202	12.8	8,921	243	1,122	140
Trojan grenade powder.	3,741	216	15.9	8 836	256	1,037.1	131.7

"The products of combustion of this explosive are such that it can be used in places with poor ventilation without danger, as there is only a trace of poisonous gases (CO) present."

Mr. John S. Swenehart, who has been conducting field tests on behalf of the college of agriculture of the University of Wisconsin, reports:

"While we have not completed all our tests on Trojan grenade powder for land clearing, we have gone far enough so that we know it is entirely usable for this work. While it seems somewhat quicker than we think should be used for stumping purposes, yet it can be salvaged to good advantage. The moisture which is encountered in our operations does not offer any difficulty after the material is properly cartridged. A No. 8 cap seems to be necessary for complete detonation, and this cap successfully and effectively detonated grenade powder where we added 2 per cent water to the material. The fumes from the powder are not very heavy. They disappear quickly and, so far as we can determine, have no effect on the user under any conditions. In strength, the material is at least equivalent to ordinary dynamites."

On the receipt of Mr. Crawshaw's report, Trojan grenade powder was allotted, under the law for public use, 600,000 pounds, stored at the general ordnance depot, United States Army, Charleston, S. C., being allotted to the Bureau of Public Roads, but as the transfer was being effected it was reported that this powder had so deteriorated in storage as to be unserviceable. Mr. J. E. Tiffany (assistant explosives engineer, United States Bureau of Mines) was at once dispatched to inspect, and from his report it is learned the explosive was packed as follows.

PACKING.

Fifteen pounds of the explosive were inclosed in a manila paper bag, which was then inclosed in a second paper bag, and tied with a string. Four such packages were placed in a box, 18 by 10 by 9 inches, made of ½-inch white pine, and of lock-cornered construction, the box being lined with paraffined paper so folded that it covered the bottom, sides, and top.

DELIQUESCENCE.

Inspection revealed that owing to the fact that this Trojan grenade powder contains about 71 per cent of easily soluble salts, it had absorbed sufficient moisture to deliquesce, and that the liquid formed had run to the bottom of the boxes, in many cases leaking out so as to saturate the exterior of the boxes and the wooden floor where they were stacked.

SENSITIVENESS.

Samples of Trojan grenade powder taken from several different boxes were made into cartridges and tested by the "Explosion by influence" test, using No, 8 detonators, and found to be too insensitive for use.

ADMIXTURE WITH TNT.

As a packing plant for cartridging surplus TNT for the Bureau of Public Roads was operating near by, it was suggested to try mixing this deteriorated Trojan grenade powder with the dry TNT, which was done, and on testing the product it was found that cartridges of the mixture containing up to 50 per cent of Trojan grenade powder were sufficiently sensitive and gave craters which were, if anything, larger in extent than those produced by TNT alone. It was also noted that the smoke from the mixture was nearly white and the report quite sharp. Furthermore, the mixture was more easily and readily packed in the cartridge cases than the TNT alone, because the latter is rather dusty. The moist Trojan grenade powder holds down this dust, and the mixture is a freer running powder than the TNT itself. Not only is the packing facilitated but the menace to the health of the packers from the existence of the dust is reduced

MODIFIED TNT.

The product formed by mixing TNT with Trojan grenade powder is styled modified TNT. As a result of such admixture there can be used to advantage in civil and industrial operations an explosive which otherwise would be more than a total loss, for it would have to be destroyed at considerable expense and always with the danger attendant on the destruction of explosives. Modified TNT, when composed of approximately equal proportions of TNT, grade III and Trojan grenade powder, appears as a gray granular substance, with occasional yellow specks. Some portions are pulverulent with fairly hard granules. The explosive is not at all dusty. When packed in paraffined paper shells, the cartridges are firm and the explosive as a whole is moderately cohesive. A cartridge 1¼ by 8 inches has an apparent specific gravity of 1.15. While for large projects the powder may be used in loose form in its containers, it is advised that the powder as a rule be packed in paper cartridge cases which are subsequently well paraffined. Modified TNT should be fired as TNT is, and with the same grade detonator.

KEEPING QUALITIES OF MODIFIED TNT.

As modified TNT contains notable amounts of the hygroscopic salts, sodium nitrate and ammonium nitrate, it will always show a tendency to absorb water from the atmosphere When these salts are present in explosive mixtures, such mixtures as a rule show a tendency to "cake" and the cartridges becomes hard or rigid. Because of this loss of plasticity by the cartridge, it becomes more difficult to puncture the cartridge in order to provide a hole for the insertion of the detonator in it; it requires more force to so tamp the cartridge as to drive it past irregularities in a bore hole and make it fit the cavity; and as a rule, as the cartridge becomes rigid, it becomes less sensitive to detonation.

On May 8 and 9, 1920, Mr. Tiffany supervised the packing at Charleston of 20 cartridges containing a mixture of approximately 50 per cent of fairly wet Trojan grenade powder and 50 per cent of grade III TNT of Hercules manufacture. These cartridges were sent to the Pittsburgh testing station where on June 7, 1920, Mr. J. A. Farr observed, in taking off the wrapper, that it required considerable force to break a cartridge in two with his hands.

Mr. Tiffany, in following up this observation on July 12, found that while, in the tests at Charleston, cartridges of modified TNT were as easily punctured for the reception of the detonator as those of 40 per cent straight nitroglycerin dynamite were, on July 12 it was more difficult to effect this puncture, although then it could be done without undue effort. A repetition of the "Explosion by influence" test showed that the sensitiveness of these cartridges to detonation had not materially decreased.

USE OF MODIFIED TNT.

Since, as was to be expected, modified TNT cartridges possess a tendency to absorb moisture from humid atmosphere and as they have shown a tendency to harden, it is advised that they be used as promptly as feasible after receipt.

FEDERAL-AID ALLOWANCES

PROJECT STATEMENTS APPROVED IN SEPTEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	80	Lauderdale	12.050	Chert and gravel	Sept. 9	$188,440.31	$94,220.15
	82	Cullman	8.020	Bituminous	Sept. 28	219,273.17	109,636.58
	85	Montgomery and Elmore		Bridge	...do	197,007.14	98,503.57
	86	....do	6.950	Gravel	...do	202,851.00	101,425.50
Arizona	36	Yavapai	3.701	.....do	Sept. 22	82,748.00	41,374.00
Arkansas	41	Clark	47.260	.....do	...do	197,598.89	76,438.00
	66	Little River	30.200	.....do	Sept. 4	170,726.05	65,000.00
	113	Lawrence	2.170	.....do	...do	21,780.87	5,400.00
	114	Lonoke	2.840	.....do	...do	22,249.37	7,800.00
	115	Madison	19.270	.....do	Sept. 3	146,027.97	60,000.00
Colorado	39	Morgan	5.902	Sand-clay	Sept. 21	47,978.59	23,989.29
	51	Cheyenne	4.886	Gravel	Sept. 17	24,857.51	12,428.75
	100	Rio Grande	3.125	.....do	Sept. 18	31,980.74	15,990.37
	101	La Plata	4.100	.....do	Sept. 28	46,678.50	23,339.25
	107	Moffat	4.235	.....do	Sept. 2	58,766.88	29,383.44
	119	Saguache	9.890	.....do	Sept. 4	53,550.20	26,775.10
	127	Lincoln	3.380	Sand-clay	Sept. 28	51,676.35	25,838.17
Florida	30	Hamilton and Columbia		Bridge	Sept. 4	89,863.40	44,931.70
Georgia	162	Gwinnett	4.900	Macadam	Sept. 28	57,117.50	20,000.00
	170	McDuffie	4.500	Sand-clay	...do	22,671.20	11,335.60
	183	Spalding	4.900	Macadam	...do	120,449.94	50,000.00
Idaho	27	Payette	17.000	Gravel	Sept. 4	204,672.05	102,336.02
	33	Nez Perce	4.000	Earth	Sept. 7	97,005.15	48,502.57
	37	Jerome	4.260	Gravel	Sept. 3	94,904.70	47,452.35
	44	Twin Falls	12.100	.....do	Sept. 2	136,279.54	68,139.77
Illinois	15	Jackson and Williamson	9.540	Earth	Sept. 20	195,580.33	48,895.08
	16	Jefferson and Wayne	14.690	.....do	Sept. 18	487,791.61	121,947.90
Kansas	67	Cloud	6.330	Concrete	...do	268,499.00	94,950.00
	68	.....do	2.250	Concrete or brick	Sept. 28	112,508.00	33,750.00
	69	Saline and Ottawa	2.000	Earth	Sept. 22	22,660.00	6,000.00
	70	Franklin	0.265	Brick	Sept. 28	13,337.50	3,975.00
Kentucky	30	Breathitt	2.500	Earth	...do	63,775.08	31,887.54
	37	Breckinridge	32.630	Bituminous	Sept. 11	938,912.29	469,456.14
	39	Knox	11.352	.....do	Sept. 2	320,646.70	160,323.35
	41	Hopkins	18.800	Gravel	Sept. 28	340,301.50	170,150.75
	42	Henderson	4.620	Earth	...do	43,329.00	21,664.50
Louisiana	60	Terrebonne	3.450	Gravel	Sept. 13	88,330.20	44,165.10
Massachusetts	47	Worcester	1.738	Macadam	Sept. 21	83,267.80	34,760.00
Michigan	47	Cass and Van Buren	15.036	Concrete or bituminous	Sept. 28	653,262.50	300,720.00
Minnesota	57	Beltrami		Gravel	Sept. 22		[1] 51,790.03
	74	Sibley		.....do	...do		[1] 54,996.00
	83	Pennington		.....do	...do		[1] 2,577.07
	90	Rock		Concrete	...do		[1] 96,535.82
	96	Winona		.....do	...do		[1] 41,498.86
	100	Steele		Concrete, brick, or asphaltic	...do		[1] 27,604.78
	105	Yellow Medicine		Gravel	...do		[1] 13,219.60
	115	McLeod		.....do	...do		[1] 11,419.25
	117	Mahnomen		.....do	...do		[1] 39,776.50
	129	Clay		Earth	...do		[1] 14,714.00
	131	Douglas		Gravel	...do		[1] 18,962.31
	132	Becker		.....do	...do		[1] 19,002.29
	133	Wauseca		.....do	...do		[1] 5,587.40
	134	Jackson		Concrete, brick, or asphaltic	...do		[1] 38,798.40
	140	Cass		Gravel	...do		[1] 21,657.00
	142	.....do		.....do	...do		[1] 20,900.70
	144	Red Lake		.....do	...do		[1] 12,840.00
	145	Pope		.....do	...do		[1] 19,134.66
	156	Beltrami		.....do	...do		[1] 8,980.00
	158	Itaska		.....do	...do		[1] 45,329.40
	165	Wright		.....do	...do		[1] 45,010.00
	166	.....do		.....do	...do		[1] 14,497.00
	65	Benton	5.000	.....do	Sept. 13	[3] 28,215.00	[3] 14,107.50
	76	Morrison	12.030	.....do	...do	[3] 46,349.09	[3] 23,174.54
	104	Renville	3.600	Concrete, brick, or asphaltic	...do	[3] 137,772.80	[3] 41,331.84
	106	Benton	14.980	.....do	...do	[3] 580,773.16	[3] 290,386.58
	151	Kittson	15.750	Gravel	...do	[3] 89,848.00	[3] 44,924.00
	152	Wadena	7.000	.....do	...do	[3] 45,155.00	[3] 22,577.50
	173	Dodge	3.980	.....do	...do	[3] 44,326.70	[3] 22,163.35
Mississippi	102	Leak	12.850	Earth	Sept. 28	71,156.25	35,578.12
Missouri	106	Dade	5.000	Macadam	Sept. 1	26,000.00	13,000.00
	138	Howell	16.760	Gravel	Sept. 2	72,068.00	36,034.00
	142	Monroe	5.000	.....do	Sept. 4	26,309.99	13,154.99
	155	Newton	17.400	Chat or gravel	Sept. 18	91,988.99	45,994.49
	157	St. Clair	4.718	Gravel	Sept. 2	47,539.14	23,769.57
	162	Greene	4.250	Clay bound, gravel, or macadam	Sept. 17	21,249.99	10,624.99
	163	Taney		Bridge	...do	72,600.00	36,300.00
Montana	130	Dawson	17.000	Gravel	Sept. 8	102,193.80	51,096.90
	135	Rosebud	10.500	.....do	Sept. 30	47,717.08	23,858.54
	138	Musselshell	6.000	Topsoil	Sept. 3	33,739.20	16,869.60
	4	Carbon	2.550	Gravel	Sept. 8	[2] 81,822.02	[2] 40,911.01
Nevada	32	Humboldt	7.500	.....do	Sept. 4	68,530.00	34,265.00
	18	Elko	4.000	.....do	Sept. 17	[2] 105,391.55	[2] 52,695.78
	31	Eureka	12.200	Gravel or crushed rock	Sept. 18	87,824.00	43,912.00
	33	Lyon	6.900	Gravel	Sept. 21	99,506.00	49,753.00
	34	Churchill	8.270	.....do	Sept. 17	107,101.80	53,550.90
	35	Clark		Bridge	Sept. 22	17,990.50	8,995.25
	36	Washoe	15.000	Gravel	Sept. 18	199,650.00	99,825.00
New Hampshire	126	Rockingham	0.660	.....do	Sept. 2	9,999.99	4,999.99
	129	.....do	1.630	Asphalt	...do	34,147.30	17,073.65
New Mexico	131	Carroll	0.700	Macadam	Sept. 8	18,000.00	9,000.00
	50	Luna	15.030	Gravel	Sept. 2	72,338.55	36,169.27
	54	Hidalgo	35.000	.....do	Sept. 6	99,601.92	48,800.96
	55	Grant	4.250	.....do	Sept. 22	38,501.10	19,250.55
	56	.....do	9.500	.....do	...do	116,011.50	58,005.75
New York	74	Greene	4.100	Concrete	Sept. 4	164,000.00	82,000.00
	76	.....do	4.200	.....do	Sept. 3	168,000.00	84,000.00
	77	Putnam	1.800	.....do	...do	102,600.00	35,910.00
	78	Orange and Sullivan	7.000	.....do	Sept. 23	399,000.00	139,650.00
	79	Orange	7.500	.....do	...do	427,500.00	149,625.00
	81	Franklin	4.800	Bituminous macadam	Sept. 24	240,000.00	84,000.00

[1] Revised statements. Amounts given are decreases from those in the original statements.
[2] Revised statements Amounts given are increases over those in the original statements.
[3] Canceled.

PROJECT STATEMENTS APPROVED IN SEPTEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
North Carolina	121	Stokes	12.100	Topsoil or gravel	Sept. 8	$104,549.50	$52,274.75
North Dakota	112	Dickey	20.000	Earth	Sept. 2	87,450.00	43,725.00
Ohio	156	Licking	5.030	Concrete	Sept. 3	250,000.00	27,000.00
	157	Hancock	2.866	do	Sept. 4	134,000.00	20,000.00
	161	Seneca	2.546	Macadam	Sept. 30	68,500.00	30,000.00
	171	Hocking	6.549	Gravel	Sept. 9	160,000.00	80,000.00
	175	do	5.351	Macadam	Sept. 4	220,000.00	82,000.00
	176	Guernsey	5.172	Concrete	Sept. 9	250,000.00	38,400.00
Oklahoma	50	Pontotoc	4.000	Gravel	Sept. 1	61,050.00	30,525.00
	44	Jackson	1.000	Concrete	Sept. 21	50,886.00	20,000.00
Pennsylvania	85	Dauphin and Perry	7.908	do	do	471,695.05	158,160.00
	86	Potter	0.953	do	Sept. 2	57,098.06	19,060.00
	87	do	1.495	do	do	109,914.53	29,900.00
	89	do	4.103	do	do	267,473.74	82,060.00
	90	Greene	2.611	do	do	151,372.18	52,220.00
	91	Lancaster	5.412	do	Sept. 3	320,312.16	108,240.00
	92	Delaware	2.838	do	do	156,969.34	56,760.00
	93	Butler	4.939	Asphalt	Sept. 4	312,304.49	98,780.00
	94	Northumberland	3.053	Concrete	do	164,533.38	61,060.00
	95	Lycoming	5.570	do	Sept. 3	412,930.98	111,400.00
	96	Cambria	4.627	do	do	359,901.90	92,540.00
Rhode Island	11	Providence	5.000	Bituminous concrete	Sept. 8	247,728.36	100,000.00
South Carolina	62	Marlboro		2 bridges	Sept. 4	53,460.00	26,730.00
	64	Lexington	4.948	Topsail	Sept. 22	37,590.16	15,000.00
	83	Union	5.639	do		[1] 39,082.80	[1] 100.00
Tennessee	38	White	13.560	Water-bound macadam	Sept. 1	341,718.38	170,859.19
Texas	88	Cass	24.220	Gravel	Sept. 17	211,978.03	58,375.00
	186	Cottle	18.460	Sand-clay	Sept. 1	83,092.40	41,546.20
	193	Bexar	6.170	Bituminous	Sept. 4	128,715.51	58,168.43
	203	Rusk	24.000	Gravel	Sept. 8	402,628.05	150,000.00
	204	San Patricio	1.700	Bridge and approaches	Sept. 22	412,500.00	200,000.00
	205	Wood	16.000	Gravel	Sept. 17	110,165.60	45,000.00
	206	Fort Bend and Wharton		Bridge	do	70,062.30	34,000.00
	208	Morris	10.684	Gravel	Sept. 29	111,148.16	48,838.95
Utah	12	Iron and Washington		do	Sept. 23	[1] 145,173.60	[1] 72,586.80
Vermont	18	Rutland		Bridge	Sept. 8	12,397.16	6,198.58
	19	Orleans	2.030	Gravel	Sept. 17	52,316.00	26,158.00
	20	Washington	0.220	Bridges and gravel	Sept. 29	33,855.80	16,927.90
Virginia	61	Augusta	4.430	Bituminous macadam	Sept. 17	111,448.70	55,724.35
	72	King William, Queen, and Essex	15.850	Sand-clay and gravel	Sept. 21	145,785.75	72,892.87
	88	Stafford	6.000	Gravel	do	99,756.80	49,878.40
	91	King George	7.500	Topsoil	Sept. 17	43,954.35	21,977.17
	103	Arlington	1.710	Concrete	Sept. 29	72,721.00	34,200.00
	106	Southampton	0.979	do	Sept. 17	57,933.70	19,580.00
Washington	78	Skamania	1.220	Gravel	Sept. 1	50,714.40	24,400.00
	79	Lincoln	2.010	Earth	Sept. 29	44,462.11	22,000.00
	80	Benton	1.613	Gravel	do	32,708.17	16,000.00
West Virginia	77	Greenbrier	9.420	Earth	Sept. 8	[2] 68,042.80	[2] 38,080.00
	99	Webster	3.300	do	Sept. 1	96,940.00	48,470.00
	104	Mineral	4.250	do	Sept. 29	55,246.40	27,623.20
Wisconsin	151	Door	7.060	Gravel	Sept. 30	79,432.70	27,000.00
	15	St. Croix	7.720	do	do	79,661.89	27,000.00
Wyoming	74	Converse	10.303	Concrete	Sept. 3	[3] 427,460.00	[3] 213,730.00
	89	Natrona	6.974	do	do	[3] 269,940.00	[3] 134,970.00
	93	Washakie		Bridge	Sept. 29	6,556.00	3,278.00
	98	Carbon	4.186	Earth	Sept. 4	32,120.00	16,060.00
	99	Goshen	3.398	Selected material	do	104,060.00	52,030.00
	101	Big Horn	1.273	Concrete	Sept. 11	49,940.00	24,970.00

[1] Revised statements. Amounts given are decreases from those in the original statements.
[2] Revised statements. Amounts given are increases over those in the original statements.
[3] Canceled.

PROJECT AGREEMENTS EXECUTED IN SEPTEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
California	44	Yolo	10.710	Reinforced concrete	Sept. 8	$278,320.60	$139,160.30
	48	Santa Clara	8.090	Concrete	do	190,439.45	95,219.72
	51	San Diego	6.675	Reinforced concrete	do	161,110.26	80,555.13
	49	Santa Cruz	5.530	Concrete	do	139,146.15	69,573.07
	52	Mendocino	17.800	Reinforced concrete	do	441,263.84	220,631.92
	55	San Diego	4.590	do	do	119,412.48	59,706.24
Georgia	48	Clark		Bituminous macadam	Sept. 23	[1] 83,211.16	[1] 31,368.52
Idaho	124	Washington	5.930	Sand-clay	Sept. 21	40,000.00	20,000.00
	8	Twin Falls and Gooding		Bridge	Sept. 28	100,000.00	50,000.00
	14	Bonneville	5.750	Bituminous concrete	do	236,263.50	95,801.64
	16	Jefferson	6.270	Earth	do	53,047.33	26,523.66
	17	Bannock	8.940	Gravel	do	90,000.00	39,925.01
	18	Nez Perce and Latah	22.100	Crushed rock	do	306,815.41	147,815.41
	25	Bingham	1.500	Bituminous concrete	do	58,459.55	29,229.77
	32	Clarke	9.329	Gravel	do	63,079.78	29,999.42
Illinois	6–x	Tazewell		Bridge	Sept. 9	74,901.49	37,450.74
	8–xz	Madison	6.720	Concrete and brick	Sept. 14	288,578.88	132,689.93
	1–13	Lee	3.347	Bituminous macadam	do	118,430.63	59,215.31
	1–19	do	1.394	do	do	83,429.65	34,940.53
Indiana	1	Elkhart		Concrete	Sept. 7	[1] 5,065.15	[1] 2,532.57
	3A	Marion and Johnson		Bituminous concrete	do	[1] 15,502.13	[1] 7,711.06
	4	Putnam and Hendrick		Concrete and bridges	do	[2] 12,513.49	[2] 10,698.02
	6A	Clay and Vigo		Concrete	do	[1] 16,743.99	[1] 8,372.00
	9A	Madison		Concrete or brick	do	[1] 2,315.43	[1] 1,157.72
	10A	Marshall		Concrete	do	[1] 8,543.03	[1] 4,271.52
	11	St. Joseph and Elkhart		do	do	[1] 16,434.29	[1] 8,217.15
	12A	Jackson		do	do	[1] 4,944.61	[1] 2,472.30
	13A	Hancock		do	do	[1] 18,100.46	[1] 9,050.73
	16B	Warrick		do	do	[2] 740.99	[1] 21,254.37
	17A	Porter and La Porte		Concrete or brick or bituminous	do	[1] 18,930.11	[1] 9,465.06
	18A	Howard and Tipton		Concrete	do	[1] 10,924.21	[1] 5,462.11
	25	Miami		Bridge	do	10,776.64	5,388.32

[1] Modified agreements. Amounts given are increases over those in the original agreements.
[2] Modified agreements. Amounts given are decreases from those in the original agreements.

PROJECT AGREEMENTS EXECUTED IN SEPTEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Iowa	17A	Dubuque	21.195	Earth	Sept. 8	$131,782.14	$50,000.00
	18	Clinton	17.579	Brick or concrete	Sept. 9	911,044.03	351,500.00
	19	Grundy	14.110	Earth	..do....	60,004.67	26,500.00
	26	Adams	9.960	....do	..do....	167,593.80	16,507.60
	32	Des Moines	4.890	Concrete	..do....	260,678.39	16,584.93
	37	Buena Vista	12.845	Gravel	..do....	50,843.98	22,600.00
	40	Muscatine	19.360	Earth	..do....	105,207.41	23,300.00
	49	Emmet	3.942	Concrete or brick	..do....	200,461.80	78,800.00
	50	Davis	10.321	Earth	..do....	106,333.26	31,150.00
	56	Henry	20.620	....do	..do....	91,796.04	45,500.00
	68	Dickinson	4.803	Concrete or brick	..do....	236,571.39	96,000.00
	77	Fremont	18.070	Earth	..do....	147,034.66	73,500.00
	78	Woodbury	2.730	Brick or concrete	..do....	160,785.62	54,785.62
	85A, B, C.	Butler	12.850	Gravel	..do....	100,746.96	50,000.00
	96	Linn	12.400	Earth	..do....	52,358.35	22,800.00
	128	Johnson	2.544	Concrete or brick	..do....	128,397.83	50,000.00
Kansas	2C, D, E.	Labette	23.420	Gravel on macadam	Sept. 2	478,461.95	239,230.97
	6	Bourbon	6.533	Bituminous macadam	..do....	221,974.61	97,995.00
Louisiana	40	Tensas	3.380	Gravel	Sept. 28	44,848.24	22,424.12
	26	Ouachita		....do	Sept. 10	[1] 6,015.99	[1] 1,053.01
Minnesota	8	Wabasha and Winona	8.960	Earth	Aug. 20	138,589.17	69,000.00
	95	Chisago	19.020	Concrete and gravel	Sept. 17	488,962.87	213,994.66
	127	Stevens	17.462	Gravel	Aug. 31	137,311.54	51,007.26
	130	Big Stone	7.688	....do	Sept. 1	90,810.55	17,103.44
	143	Beltrami	6.210	....do	Sept. 2	52,948.99	20,000.00
	148	Hennepin and Dakota	11.670	....do	Sept. 1	367,946.46	100,000.00
Mississippi	84	Jefferson	35,270	Clay and gravel	June 30	365,304.51	182,652.25
New Hampshire	50	Cheshire		Gravel	Sept. 3	[1] 1,139.60	[1] 569.80
	52	Sullivan and Merrimack		....do	..do....	[2] 2,620.85	[2] 1,310.42
	66	Carroll		....do	..do....	[1] 1,493.42	[1] 746.71
	83	Strafford	1.020	....do	Sept. 8	21,875.26	10,937.63
	89	Merrimack	0.578	....do	Sept. 3	17,874.59	8,937.29
	99	Coos	1.100	....do	Sept. 1	17,314.22	8,657.11
	108	Grafton	1.930	Bituminous macadam	Sept. 8	64,813.92	32,406.96
	109	Strafford	0.797	Gravel with tar surface	Sept. 3	15,013.51	7,506.75
	110	Merrimack	1.246	Modified asphalt	Sept. 1	24,993.04	12,496.52
	113	Hillsborough	0.410	Bituminous macadam with surface of tar treatment.	Sept. 3	5,951.74	2,975.87
	117	Grafton	0.940	Bituminous macadam	..do....	25,087.42	12,543.71
Ohio	31D, E	Union	8.238	Reinforced concrete or bituminous macadam.	Sept. 10	282,000.00	83,800.00
	34	Erie		Reinforced concrete	Sept. 23	[1] 17,000.00	[1] 17,000.00
	46	Ashland		Concrete or monolithic brick	Sept. 24	[1] 50,040.00	[1] 4,000.00
	61	Wayne	4.082	Concrete or brick or bituminous macadam.	Sept. 10	158,000.00	69,000.00
	93	Gallia	6.248	Bituminous macadam	Sept. 29	186,000.00	92,500.00
	112	Jackson	2.332	Concrete or bituminous macadam	Sept. 22	120,000.00	42,500.00
	137	Sandusky	6.542	Brick or bituminous concrete	...do....	435,500.00	106,000.00
	151	Clermont	5.489	Bituminous macadam	...do....	189,700.00	88,000.00
Oregon	11	Baker		Earth	Sept. 15	[2] 41,814.85	[2] 23,907.42
	32	Lake	11.090	Gravel	...do....	140,560.42	70,280.21
	36	Wasco		Earth	Sept. 9	[1] 21,442.74	[1] 10,721.37
	35	....do	8.970	....do	Sept. 15	285,963.97	142,981.98
	37	....do	12.500	....do	...do....	299,204.40	149,602.20
	39	Jefferson	17.440	Broken stone	...do....	174,002.40	87,001.20
	40	Wallowa	8.390	Earth	...do....	123,569.71	61,784.85
	41	Gilliam	6.900	Broken stone	...do....	180,158.00	90,079.00
	42	Umatilla	21.880	Broken stone or gravel	...do....	129,800.00	64,900.00
	43	Crook	15.150	....do	...do....	178,237.51	89,118.75
	46	Malheur	0.891	Concrete	...do....	30,744.67	15,372.33
	30	Klamath	13.900	Broken stone or gravel	...do....	160,608.97	80,304.48
Pennsylvania	15B	Beaver	5.334	Reinforced concrete	Sept. 3	467,322.46	106,680.00
	20D	Adams	9.732	....do	...do....	562,766.95	194,640.00
	33C	Luzerne	3.196	....do	Aug. 8	239,021.53	63,920.00
	71	Lawrence	5.423	....do	Sept. 1	352,364.19	108,460.00
	72	Adams	8.740	....do	Sept. 3	533,961.82	174,800.00
	73	Franklin and Adams	8.364	Concrete	Aug. 30	459,540.86	167,280.00
	76	Mercer	9.179	Reinforced concrete	Sept. 1	643,753.02	183,580.00
	77	Monroe	7.280	....do	Sept. 2	567,596.92	145,600.00
	79	Montgomery	5.655	....do	Sept. 1	349,454.27	113,100.00
	80	Crawford	3.432	....do	Aug. 30	230,420.96	68,640.00
	83	Montgomery	4.915	....do	Sept. 3	309,546.60	98,300.00
	78	Monroe	7.094	....do	Sept. 1	554,859.09	141,880.00
	82	Erie	8.466	....do	...do....	572,831.16	169,320.00
South Carolina	17	Calhoun		Bridges	Sept. 28	[2] 4,944.19	[2] 2,472.10
Texas	107	Runnels		....do	Sept. 23	72,963.58	36,481.79
	119	Wichita	10.000	Concrete	...do....	568,702.68	100,000.00
	133	Kimble	30.470	Gravel	...do....	201,492.45	100,000.00
	134	Polk	22.070	Stone macadam, bituminous top	...do....	508,638.61	127,159.65
	145	Tom Green	10.000	Water-bound macadam, surface treatment.	...do....	266,674.59	100,000.00
	160	Upshur	9.015	Gravel	...do....	78,335.95	39,167.97
	167	Delta	11.700	Concrete or gravel	...do....	279,022.45	110,000.00
Virginia	15	Washington		Earth	...do....	[1] 98,464.30	[1] 49,232.15
	16	Botetourt and Rockbridge		Macadam	...do....	[1] 7,045.78	[1] 3,522.88
	20	Southampton		Gravel	...do....	[2] 68,357.47	[2] 34,178.73
	27	Smythe	5.700	Water-bound macadam	Sept. 25	95,608.35	47,804.17
	52	Lee	5.280	....do	Sept. 23	100,381.27	50,190.63
	59A	Nansemond	4.460	Concrete	...do....	169,470.07	84,735.03
	46A	Rappahannock	3.086	Macadam	...do....	82,914.11	41,457.05
	66	Chesterfield	8.939	Concrete	Sept. 25	346,563.69	173,281.84
	67	Dickenson	5.920	Bituminous macadam	Sept. 23	138,008.39	69,004.19
	70A	Campbell	3.110	....do	...do....	102,019.00	51,009.50
	79	Prince William and Stafford	0.549	Concrete	Sept. 25	48,447.48	17,607.98
	81A	Henrico	2.480	Bituminous macadam	Sept. 23	69,666.80	34,833.40

[1] Modified agreements. Amounts given are increases over those in the original agreements.
[2] Modified agreements. Second revision. Increase.

PROJECT AGREEMENTS EXECUTED IN SEPTEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Washington	30	Skagit		Concrete	Sept. 8	[1]$21,000.09	[1]$10,500.00
	52	Stevens	7.720	Gravel	...do	104,986.17	52,000.00
	53	....do	5.990	....do	...do	89,502.09	44,000.00
	54	Grays Harbor	3.640	Earth	...do	55,429.99	28,500.00
	55	Thurston	6.200	Concrete	...do	258,598.06	125,000.00
	57	....do	1.990	....do	...do	72,114.02	36,000.00
	58	Mason	1.970	Gravel	...do	27,156.36	13,500.00
	59	Snohomish		Bridge	...do	20,577.81	10,000.00
	60	....do	3.090	Concrete	...do	107,342.18	53,000.00
	61	Lewis	1.240	Gravel or crushed rock	...do	37,146.56	18,573.28
	62	Yakima	5.760	Concrete	...do	245,598.40	82,700.00
	64	Snohomish	0.990	....do	...do	39,750.26	19,800.00
	66	Garfield	7.420	Crushed rock	...do	185,357.37	90,000.00
	67	Mason	5.490	Gravel and earth	...do	112,621.34	56,000.00
	68	Grant	3.340	Gravel	...do	51,475.16	25,000.00
	69	Chelan	1.670	Concrete	...do	66,688.71	33,000.00
	70	Lewis	3.960	Earth	...do	68,416.92	34,000.00
	73	Pacific	7.650	....do	...do	279,138.64	138,000.00
	74	Skagit		Bridge	...do	11,817.85	5,400.00
	75	Okanogan	4.140	Gravel	...do	27,794.80	13,500.00
	76	Pierce	0.500	....do	...do	34,733.60	12,736.25
Wyoming	26	Lincoln	9.174	Earth	Sept. 18	43,998.70	21,999.35
	65	Big Horn	3.172	Selected material	Sept. 20	33,371.80	16,685.90
	70	Washakie	2.902	....do	...do	30,643.21	15,321.60
	75	Uinta	2.489	....do	...do	22,622.00	11,311.00
	84	Park	6.954	....do	...do	88,044.77	44,022.38
	85	Natrona	10.000	....do	...do	111,211.40	55,605.70
	86	Johnson	6.477	....do	...do	83,376.26	41,688.13
	90	Hot Springs	3.228	....do	...do	45,973.99	22,986.99

[1] Modified agreements. Amounts given are increases over those in the original agreement.

EASTERN STATES PLAN THEIR SNOW REMOVAL WORK FOR COMING WINTER

[Concluded from page 12.]

WHERE REMOVAL IS BY HAND.

When snow must be removed by hand, it is important that the laborers be furnished with large scoops and that even at some additional first cost the snow be so piled that it will hinder rather than assist the refilling of the locations that have been cleared. It is not generally advisable to load the snow in trucks and remove it entirely, but this is sometimes done, and, indeed, when the cuts that have to be made are both wide and deep this may be cheaper than casting to one side. Snow so removed can generally be disposed of by the simple process of dumping it over the edge of the nearest high fill.

As noted before, the most expensive item in snow removal is the excavation by hand of the drifts that have gotten beyond the capacity of the snowplows. For such work as this there are now manufactured rotary plows that will cut out these drifts and cast the snow considerable distances to the side of the cut which they make. As yet these rotary plows have not come into very general use, largely, it is thought, because the removal of snow from the highways is a comparatively new thing. Their use is, however, bound to increase, for it is not at all likely even after all of the preventative measures noted above have been taken that drifting will be so thoroughly eliminated that the snowplows operated by the modern trucks can fully cope with the situation. Rather, it seems to the writer, that it will prove advisable to supplement the present equipment in most States by the addition of enough heavy plows so that a working space can be kept clear even through the cuts that are known to drift full during severe storms, thereby insuring that full efficiency can be had from the other equipment.

Just how rapidly this change in snow-removal equipment will be made will depend on the development of satisfactory rotary plows, but it can hardly be put off much longer, for the cost of shoveling out deep drifts is very expensive.

○

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS

Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock. 15c.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A Summary.
*393. Economic Surveys of County Highway Improvement. 15c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918. 15c.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and classification of Rocks for Road Building, including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure. (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir *89. Progress Report of Experiments with Dust Preventatives. 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction. 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
*Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918. 15c.
Public Roads Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the U. S. 1919.
Public Roads Vol. III, No. 29. State Highway mileage 1919.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

B. Y. Sept. 727. Design of Public Roads.
B. Y. Sept. 739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D-3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D-8. Tests of Three Large Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

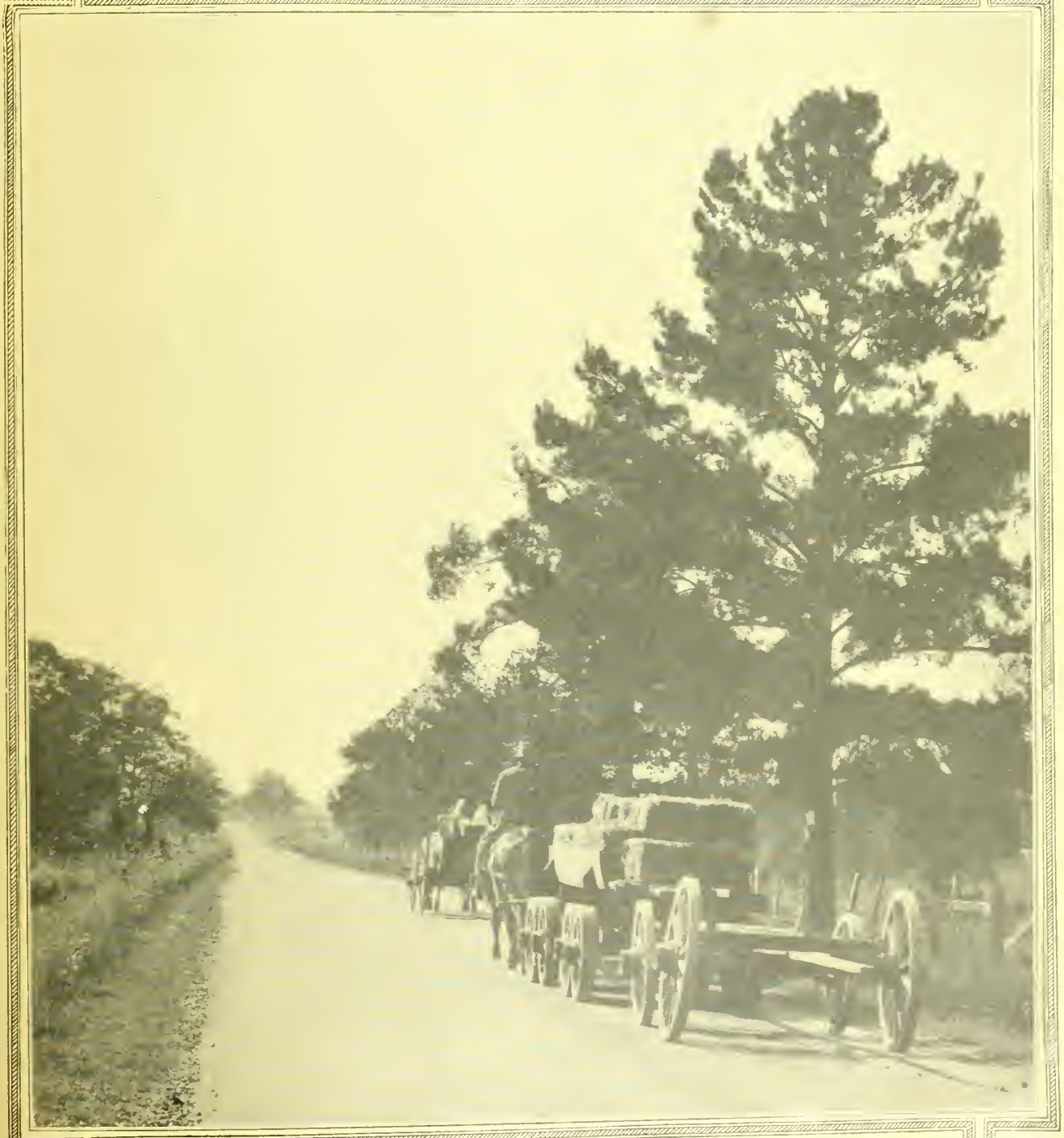
* Department supply exhausted.

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 31 WASHINGTON, D. C. NOVEMBER, 1920



TEXAS FEDERAL-AID PROJECT NO. 21, FROM GLADEWATER TO LONGVIEW

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page

Superelevation and Easement as Applied to Highway Curves 3
A. L. Luedke and J. L. Harrison

TNT a Success in Road Work 13
Luke E. Smith

Map of Roads to be Cleared of Snow 14

The How and Why of Truck Impact 16
Earl B. Smith

Design and Construction of Bridge Foundations 19
Llewellyn N. Edwards

Federal Aid Allowances 25

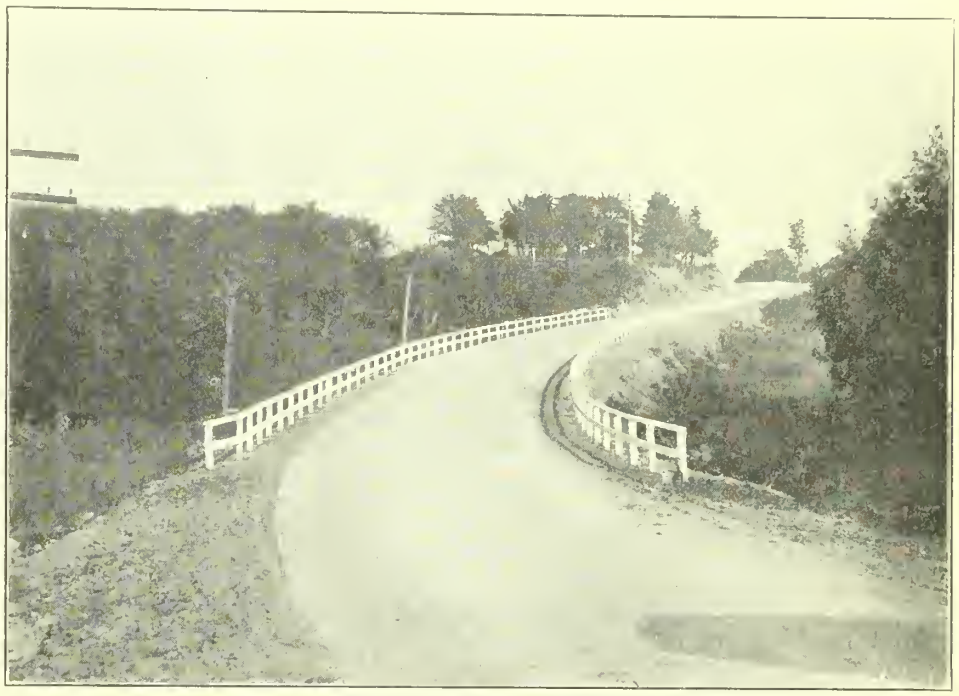
THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

SUPERELEVATION AND EASEMENT AS APPLIED TO HIGHWAY CURVES

By A. L. Luedke, Engineer Economist, and J. L. Harrison, Senior Highway Engineer, Bureau of Public Roads.

UNTIL recently, highway builders have given very little attention to the superelevation and widening of curves. As long as all vehicles were horse drawn there was, of course, little need for either and, for some time after the automobile brought about a general speeding up of highway traffic, it was thought by many engineers that the omission of these features would do more to promote safety by discouraging speed on the curves than would their inclusion by making higher speeds safe. No doubt the fact that many curves on the older highways were extremely sharp, as judged by present standards, and the line of sight often obstructed by embankments or vegetation, has made the discouragement of speed desirable. However, that, in practice, this theory has not been productive of safety is demonstrated by the alarming multiplication of accidents where it has been applied. Its failure seems to be due to the fact that automobiles are not driven much slower on the curves than they are on tangents, and that there is a marked tendency for drivers who belong on the outside to seek the inside of the curve for, by swinging to the inside, the line over which a vehicle is driven is considerably flattened. Moreover, when this is done, the crown produces the same effect as a certain amount of superelevation, whereas, when a car is driven on the outside of the curve, the crown acts with the centrifugal force and tends to cause skidding. On blind curves this practice results in collisions. These may be largely avoided by recognizing this tendency and providing curves of ample radius and proper superelevation so that it is as safe and as comfortable to follow the outer edge of the pavement as to cross to the inner edge. Drivers can then, without inconvenience, keep to their own side of the road or if, carelessly, they take the wrong side, they can swing back to the proper side in emergency, without danger of accident.



ON WIDENED CURVES WHICH ARE IMPROPERLY BANKED THE TRAFFIC SWINGS TO THE INSIDE OF THE CURVE TO TAKE ADVANTAGE OF THE CROWN, LEAVING AN UNTRAVELED LUNE ON THE OUTER EDGE.

The railroad builder has long provided superelevation and easement on all curves. His reason for so doing has lain partly in the fact that easement and superelevation reduce the cost of maintaining curves, partly in the fact that easement curves favorably effect the wear and tear on equipment, but principally in the fact that easement and superelevation are necessary for the comfort of the passengers traveling on the fast trains. For this latter reason the tendency on the part of most railroads has been to base both easement and superelevation on the speed of the express trains, thereby insuring the greatest comfort for the higher classes of traffic. For the highway builder the problem is a little more complex. Highway traffic is made up of a variety of vehicles capable of and habitually propelled at widely varying speeds. It must also be recognized that these vehicles are propelled in different ways and carried on tires having widely different characteristics. Moreover, the smoothness of the surface of the various types of highway pavements leads to differences in the tendency of these vehicles to skid or to slide in rounding curves. It is necessary to consider all of these factors in arriving at a proper amount of superelevation. Stated in different terms, the problem of the highway engineer is not merely one of providing such superelevation that all vehicles proceeding at a legal speed can round these curves without danger,

but of so designing curves that horse-drawn traffic, for instance, which moves at only 3 or 4 miles an hour can use the highway without danger of sliding to the inside edge of the pavement. Indeed it is because these two types of traffic establish such opposing limitations on design that an analysis of the problem of superelevation is necessary.

MATHEMATICAL ANALYSIS OF SUPERELEVATION.

Complete superelevation consists in so tilting the surface of the road that the center of gravity of any vehicle using it will be moved toward the inside of the curve by an amount sufficient to balance the effect of the centrifugal force. The amount of the superelevation required in order to balance the centrifugal force depends on the speed at which a vehicle is moving and the radius of the path in which it is traveling. The relationship of these factors is shown in figure 1.

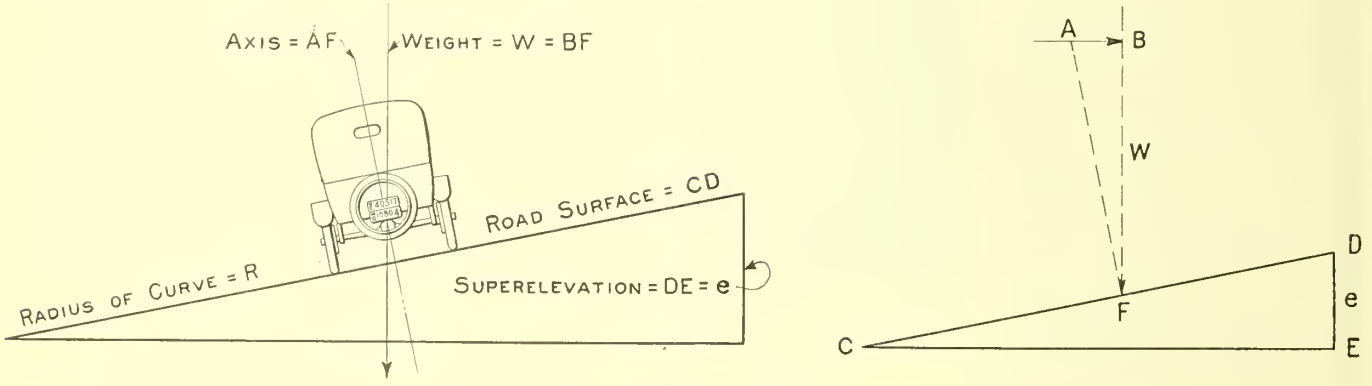


FIG. 1.—Diagram of forces.

According to the mechanics of moving bodies (see fig. 1),

$$AB = \frac{Wv^2}{gR} \tag{1}$$

where AB is the centrifugal force, W the weight of the body in pounds, v the velocity in feet per second, g the acceleration of gravity or 32.16 feet per second, and R the radius of the curve in feet.

From similar triangles in figure 1,

$$AB = \frac{We}{CE} \tag{2}$$

Equating (1) and (2)

$$Wv^2 = \frac{gR \cdot We}{CE} \tag{3}$$

or,

$$e = \frac{CE\, v^2}{gR} \tag{4}$$

Substituting 1 foot for CE, reducing v from feet per second to miles per hour, and substituting 32.16 feet for g, there results:

$$e = \frac{V^2}{15R} \text{ (nearly)} \tag{5}$$

in which e is in feet, V in miles per hour, and R in feet. Thus, for a speed of 25 miles per hour (for the relation of other rates of superelevation to various speeds and radii see fig. 2) on a curve having a 200-foot radius, the superelevation theoretically required for the complete counterbalancing of the centrifugal force is 0.21 foot per foot of width, or 3.8 feet for an 18-foot pavement. It is evident that this superelevation exceeds what may be considered a safe amount for the slow moving traffic or, in other words, that such superelevation would cause the slow moving iron-tired traffic to slide toward the inner edge of the road. Hence, it becomes necessary either to establish arbitrary rates of superelevation consistent with the needs of the slower moving traffic or to use curves of longer radius.

Just where such sliding can be expected to take place will depend, of course, on the nature of the surfacing and its condition (that is, whether dry, wet, or covered with frost) as well as on the nature of the tires, but it is safe to say that, as a general practice the pitch of the surfacing should not exceed 10 per cent. Such a pitch, however, will provide complete superelevation for a speed of only 17 miles per hour on a curve having a radius of 200 feet, and almost none of the traffic on our highways moves at a speed as low as this. Indeed a very ordinary speed is from 25 to 30 miles per hour. Moreover, this speed is, generally speaking, a legal speed. Therefore, if the traffic is to be completely protected, even within the legal speed limits, not to mention conditions which will frequently arise as a result of reckless driving, and if, at the same time, a pitch of 1 foot in 10 is the maximum that can properly be adopted in superelevating curves, it necessarily results that where the legal speed is 25 miles per hour the minimum radius of curvature for which full protection can be given is about 415 feet and where a speed of 30 miles per hour is legal the minimum radius of curvature for which full protection can be given is 600 feet.

On the other hand, it is generally assumed that full superelevation is unnecessary. Thus the committee on recommended practices for concrete road and street construction has recommended a maximum superelevation of three-fourths inch per foot of width on curves having a radius of 150 feet or less. This is

complete superelevation for a speed of not quite 12 miles an hour on curves having a radius of 150 feet. On curves having a radius of from 150 feet to 500 feet the superelevation recommended is at the rate of one-half inch per foot of width, and for curves having a radius of over 500 feet the normal crown is recommended. These recommendations provide complete superelevation for a speed of 11 miles per hour on a curve of 200-foot radius, for 17 miles per hour on a curve of 500-foot radius, while for curves having a radius of over 500 feet the effect of this recommendation is to trust to the stability of the vehicle itself to resist the total centrifugal force plus the slight addition thereto that results from the fact that the crown on the outer edge of the curve will increase rather than decrease the effect of the centrifugal force and consequently the tendency to skid.

These recommendations have been analyzed in this fashion for the purpose of emphasizing the fact that many authorities, and with entire justice, assume that the adequate protection of the traffic does not imply a superelevation which will counterbalance all of the centrifugal force. Indeed, an analysis of the above recommendations would seem to indicate that the authors of these recommendations have assumed that, if the centrifugal force resulting from a speed of 10 to 15 miles per hour is compensated, the stability of any well-built and properly driven vehicle will take care of all the additional side thrust that results from operating the vehicle within reasonable limits of speed. This is, of course, correct. Moreover, the introduction of superelevation to counterbalance part of the centrifugal force, though correcting the tendency of drivers to hug the inside of the road by rendering the outside as safe as the inside, does not so completely protect the traffic that it tends to correspondingly increase speeding on the curves.

METHODS OF ACCOMPLISHING SUPERELEVATION.

The desired amount of superelevation may be secured in a number of ways, but is generally secured either—

(1) By revolving the surface about the center line as an axis; or

(2) By revolving the surface about the inner edge of the pavement as an axis.

There are some modifications of these two methods but, in most cases, the present practices in superelevation are in all essential points based on one of these methods. These methods are outlined in figure 3.

The effect of these methods upon the grade of the center line and of the ditches is worthy of mention. If the surface is revolved about the center line as an axis the effect will be to lower the inside edge of the pavement and to raise the outside edge. This, in cuts, will depress the grade line of the inner ditch and raise the grade line of the outer ditch. If the surface is revolved about the inner edge as an axis, the effect will be to raise the grade of the center line, causing a slight hump in the grade. However, as the hump falls on the curve and is, therefore, not noticeable, this is a matter of little consequence. This latter method of superelevating curves has the tendency to increase the amount of fill.

RATE OF TRANSITION.

The success of the superelevation of highway curves is considerably affected by the rate of transition that is adopted. No superelevation is required on tangents. As soon as a circular curve is entered the full

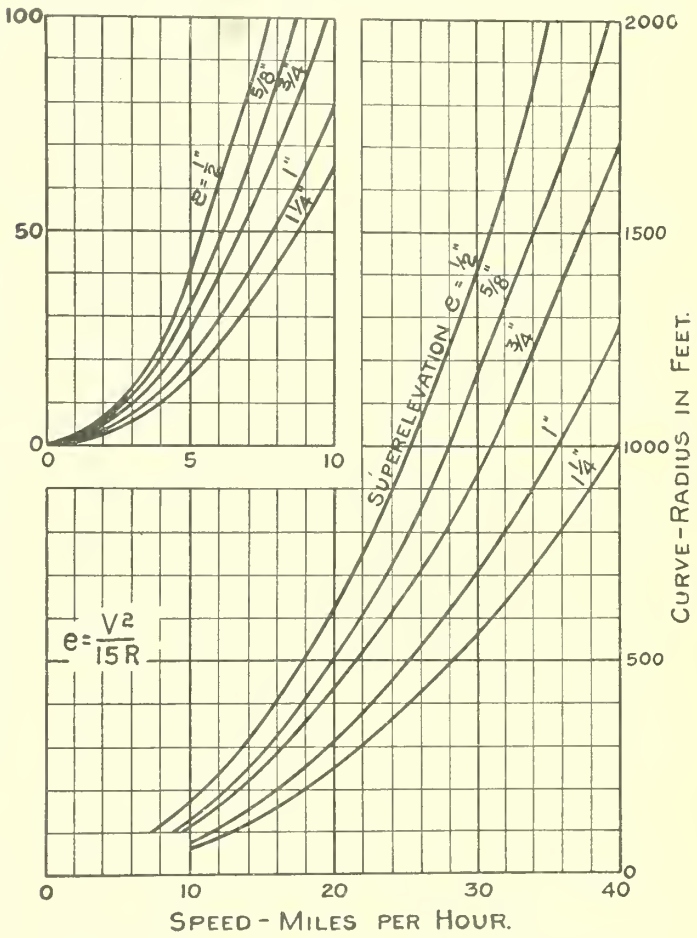


FIG. 2.—Curves showing relation between speed, radius, and superelevation on curves.

superelevation is required. Obviously, it is not possible to change from the nonsuperelevated section to the fully superelevated section abruptly at the point where tangent and curve meet. The only course possible is to employ an approach section in which the superelevation will increase from zero to the desired maximum. The proper development of the superelevation in this approach section is almost as important as the superelevation of the curve itself. If the change is made too abruptly the result will be unsightly and the shock of passing from the tangent to the curve disagreeable. Moreover, it is almost as illogical to develop the superelevation on the tangent as it is to develop it after the full circular curve has

been reached. The only correct practice is that which is indicated by the theory as expressed in the equation $e = \frac{V^2}{15R}$. The velocity V being assumed constant, it follows that as the superelevation, e, is increased, the radius, R, should be decreased, which is equivalent to saying that the superelevation should be developed on a transition curve the radius of which should decrease from infinity at the point where the superelevation is zero to a minimum equal to the radis of the circular curve where the superelevation reaches its maximum, i. e., at the P. C. In railroad practice the relation between radius and superelevation is worked out very carefully and conforms very closely to the theoretical relation. In highway design it is not necessary that the radius of the transition curve be made to vary so exactly with the change in superelevation, because the vehicle traveling on the highway is not confined to a fixed track as the railroad train is. If the curvature of the surfaced way conforms approximately to the theoretical requirement, the vehicle, by departing slightly from a concentric course, can take a natural path without being forced to leave the surfaced road. All that is necessary, therefore, is that the curvature of the road shall conform to the theoretical curvature with sufficient accuracy so that it will not be necessary for drivers of vehicles to pass beyond the center or the side of the road in following a natural course.

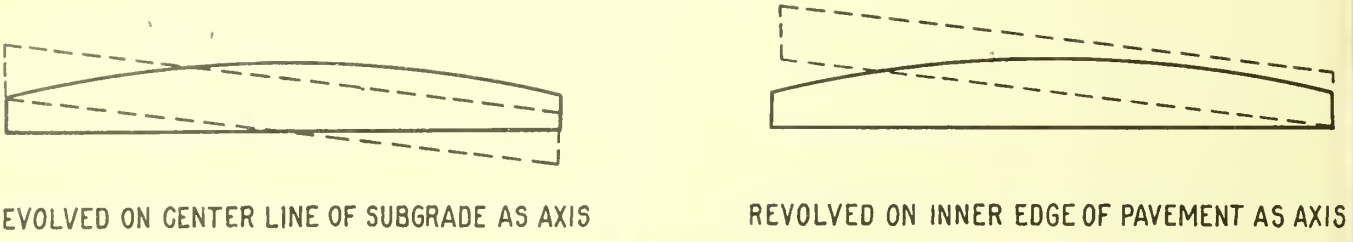


FIG. 3.—Methods of accomplishing superelevation.

Current American highway practice employs three approximations, as follows:

(1) A circular curve of long radius on the inner edge of the road.
(2) Compound circular curves in which the principal circular curve is joined to the tangent by means of one or more circular curves of longer radius.
(3) Spiral transition curves, similar to these commonly used in railroad work.

A satisfactory method, which has, for some reason, not been used in this country, consists in the use of parabolic instead of circular curves. The parabola provides its own transition.

TRANSITION NEEDED ON OUTSIDE.

Whatever form of transition curve is adopted, there is just as much need for the use of it on the outer edge as on the inner edge of the pavement. One of the principal reasons for superelevating curves, as previously pointed out, is to prevent the cars which belong on the outside of the curve from cutting to the inside. To accomplish this purpose, the outside of the curve should be made fully as safe and as easy to drive around as the inside, else the motorist will take the easier course offered by the inside. This means not only that the fully superelevated section of the circular curve should be a plane surface but that the approach to full superelevation should be approximately the same on both sides of the road, and that approximately the same relation of superelevation to radius of curve should be maintained on both edges in the transition section.

Desirable as it is to maintain like conditions on both sides of the road, it is a fact that the present practice does not provide this condition. Without exception the State standards provide no transition curve for the outer edge; and some of the States approximate the transition requirements of the inner edge by providing a circular curve of long radius, a practice which leaves it to the motorist to make his own transition on the widened curve which results. It is, of course, impossible to ease the outer edge of a curve treated in this manner, since the use of a parallel curve on the outer edge would simply result in a road with a circular curve, although it be of somewhat longer radius.

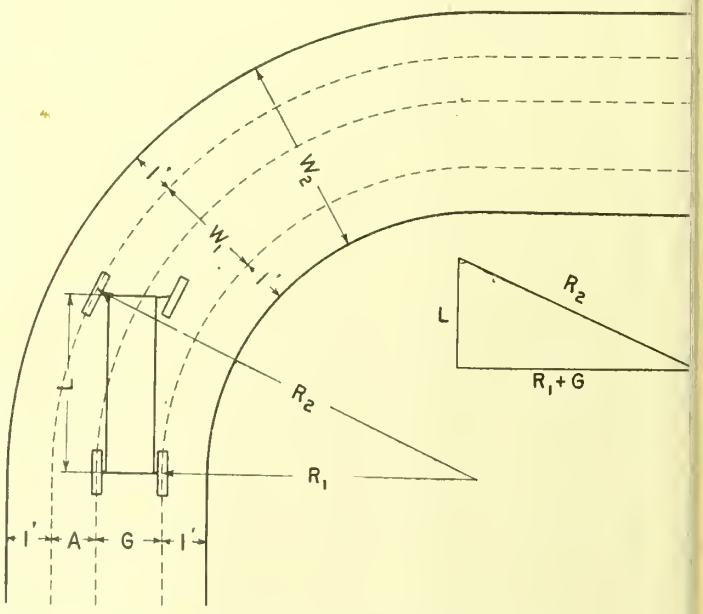


FIG. 4.—Diagram showing extra width required in turning.

Not only does the present practice overlook the need for transition on the outside of curves, but by providing for the elimination of the crown between the P. T. C. and the P. C. it creates an unfavorable condition of superelevation for the car which is traveling on the outer edge in this section in which the superelevation is being developed. Approximately half of the transition section is required to eliminate the crown. In this distance, the motorist, who has begun to round the curve at the point where the transition curve begins on the inner edge, has the advantage of no superelevation if he continues along the outer edge. The result is that he tends to move over to the inside of the curve, and when the full circular curve is reached he is found well toward the center. Fortunately the added width of pavement which results from the use of the transition curve on the inside and the plain circular curve on the outside, leaves room for passing cars, but the extra width on the outside is practically useless.

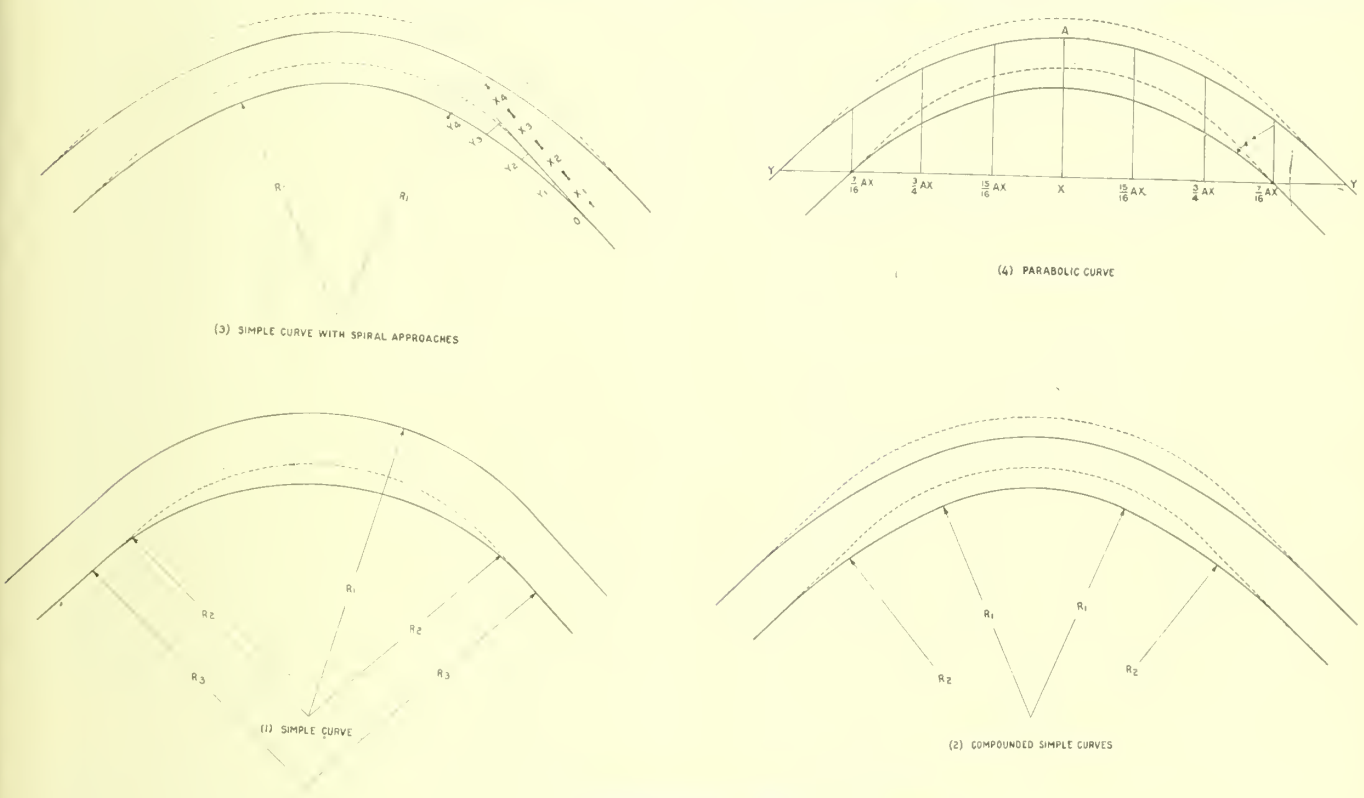


FIG. 5.—Types of transition curves and method of widening.

This matter sums itself up in the simple statement that both transition and superelevation should apply to the inside and the outside of the curve alike.

FLAT SECTION AT P. T. C. ADVISABLE.

But to bring this about it is necessary to start at the P. T. C. with a crownless section and to carry this section to the P. T. T. Moreover, the simplest plans are the most accurately carried out in the field and therefore it is well to have the crown reduced to zero at the P. T. C. and built up from zero at the P. T. T. from a purely construction standpoint. This can be rather simply accomplished by raising the subgrade at the P. T. C. by an amount equal to the difference between the crown thickness and the thickness of the flat slab section and setting the forms to taper back. By allowing 10 feet per inch of crown height, skilled workmen can change from the full crown to a crownless section in a very acceptable manner, performing the work entirely by eye. This method applies to macadam and gravel roads as well as to roads of the hard-surface types.

The amount of crown that is used on the various types has been more or less fixed by custom but is, in theory at least, governed by practical considerations involving the drainage of the surface of the road. There has, therefore, been some objection to the creation of even short sections of highway not liberally crowned. This objection can be carried too far. Indeed, in designing curves, it has often resulted in plans which have been so difficult of accomplishment under normal field conditions that they justify the impression that, in spite of the common objections to a crownless section the greater accuracy of construction which will result from arriving at the P. T. C. with a flat section will more than justify the general adoption of this procedure. There can, of course, be no objection to this as applying to hard surfaced roads, for in such types the immediate drainage of the road surface is of minor importance.

COMPLETE SUPERELEVATION NOT NEEDED.

It has previously been shown that the equation of superelevation is $e = \frac{V^2}{15R}$ from which it naturally follows that for any fixed value of V, that is, for any given speed, e should vary inversely as the factor $15R$. Curves must, of course, be designed for one speed, and where there is a legal speed limit, they should be designed so that that speed is actually a safe speed. As previously pointed out, this does not imply that the superelevation shall fully counterbalance the centrifugal force at that speed, but it does imply that there shall be a policy as to the relation of these factors, and an established minimum of protection offered on all curves. Just what this minimum should be will depend somewhat on local conditions. The present practice of New York State, which provides as a standard a 300-foot minimum radius of curvature and superelevation to compensate for a speed of 20 miles per hour on curves of this radius, with an increasing amount of compensation (see Table 1) for curves of longer radius (i. e., where the unobstructed sight distance is greater) is the highest standard so far established. However, where this high standard can not be adopted, a minimum radius of curvature of 200 feet with superelevation to compensate for a speed of 15 miles an hour, and increasing compensation for curves with longer unobstructed sight distances should prove quite satisfactory.

Let it be assumed that it has been established that no curve will be constructed the superelevation on which will compensate less than 15 miles per hour. If, then, a curve of a radius of 200 feet is to be built and the transition is to be composed of two curves having radii of 800 feet and 400 feet, the superelevation should be 0.019 foot per foot of width for the first curve, 0.038 foot per foot of width for the second curve, and 0.075 foot per foot of width for the full curve. For all practical purposes a linear increase in the superelevation from 0 at the P. T. C. to 0.075 foot at the point of full curvature would, in this case, be satisfactory and, by many engineers, preferred to any other system. Such a transition should apply, with proper adjustment for the longer radii to the outside as well as the inside of the pavement.

If a closer control is desired it can be readily obtained by using either spiral transition curves or parabolic curves, instead of compound circular curves. The peculiar virtue of these curves lies in the fact that they closely approach the path actually traversed by a fast-moving car. It takes an appreciable time to operate the steering device on an automobile. During this time the car is moving rapidly ahead. The result is not a circular path, but one the radius of which constantly changes as the wheel is turned. From the standpoint of the driver of such a car the minimum radius to which he must drive is, therefore, of vastly less importance than that he be given a proper space in which to conform the direction in which his car is moving to that radius. Moreover, from the standpoint of the driver, it is just as simple a matter to operate his vehicle on a curve of constantly changing radius as on a curve of uniform radius, providing the rate at which the radius changes is within the normal control limits of his car. He would, therefore, prefer to drive over a sharp curve having proper approaches rather than to operate on a curve of longer radius to which there are no approaches. For this reason both the spiral transition and the parabolic curve are pleasant to drive over and, relatively, much safer than simple circular curves. Moreover, as the actual radii of these curves shortens from infinity to the minimum used by well-known mathematical rules the superelevation can be readily adjusted. In the case of the parabola it can be handled, where superelevation is by revolution on the inner edge, by the simple process of treating the elevation of the outer edge as a parabolic vertical curve having its apex at the apex of the horizontal curve.

Short parabolic curves are the simplest of all curves to lay out. They depart from standard American practice, however, in that they are chained in—no instrument work being required—and that, in practice, they are generally figured in the field—no tables being used. This has, no doubt, prejudiced some against their use but as both the calculations and the chaining are very simple this prejudice rapidly disappears wherever they are introduced. Spiral transition is so fully treated in texts on railroad engineering that it will not be discussed here except to say that, for curves as sharp as those used in highway work, the spiral transition sections will usually be laid off by offsetting from the tangent. Where spiral transition curves are used, as where compound circular curves and parabolic curves are used, the outside edge of the pavement as well as the inside edge should be treated.

No matter what kind of curves are used, the length of the transition should vary inversely with the radius of curvature of the full curve. There are, at present, no well defined standards governing this matter but current practice suggests that it will probably be found that a 100-foot transition section will give easy transition to a curve of 200-foot radius. This is equivalent to a period of nearly 3 seconds in which to divert a vehicle moving at the rate of 25 miles an hour, from a straight course to a circular course of the above radius. For curves of longer radius, the diversion is not as great and the transition can be correspondingly decreased.

WIDENING OF CURVES.

Because of the fact that the rear wheels of ordinary vehicles are fixed causing them, when rounding curves, to travel on a different radius from the front wheels it is advisable that some added width of surface be provided on curves of short radius. This

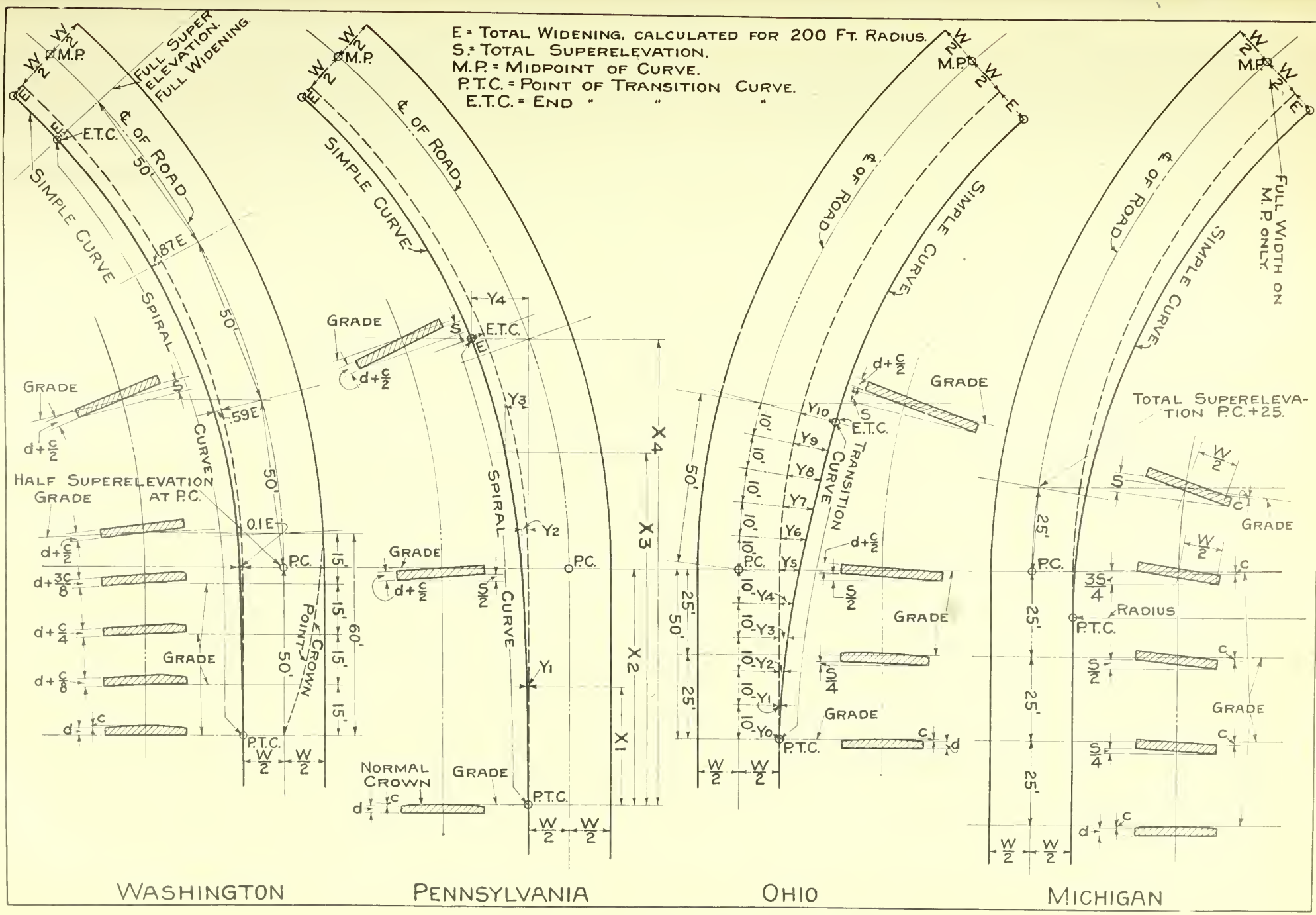


FIG. 6.—Typical methods of superelevation and widening in use by the States.

added width should vary with the radius of the curve, the gauge of the wheels and the length of the vehicle as outlined in figure 4. By consulting this figure it will be seen that,

$R_2^2 = (R_1 + G)^2 + L^2 \qquad W_1 = R_2 - R_1 \qquad A = R_2 - (R_1 + G)$

in which

R_2 = Radius of inner rear wheel curved track in feet.
R_1 = Radius of outer front wheel curved track in feet.
G = Gauge of wheels in feet.
L = Wheel-base length in feet.
W_1 = Full width required for clearance in feet.
A = Amount of widening required in feet.

Thus, a touring car having a 136-inch wheel base and 56-inch gauge, turning on an outer front wheel radius of 21.2 feet, would be turning on an inner rear-wheel radius of 13.2 feet and would require an added width of 3.3 feet. Similarly, a 5-ton motor truck of 168-inch wheel base, turning on an inner rear-wheel radius of 25 feet would require an added width of 3.1 feet to maintain the same clearance provided for on tangents. Fortunately, the radii of the curves usually used are greater than the 13.2 feet and 25 feet assumed in these examples, but they illustrate why it may be advisable to widen the pavement on sharp curves. For a 150-foot radius, the added widths would be 0.3 foot for the touring car, and 0.4 foot for the 5-ton truck.

The ordinary procedure in widening the pavement on curves is to increase the width by an amount which is considerably greater than what is theoretically required to compensate for the fact that the wheels of a vehicle do not track. Where such widened curves are properly banked it will be observed (1) that the added width on the inside of the curve is being constantly used (2) that both the inside and outside lines of traffic are proceeding in paths that resemble a parabola, and (3) that a width on the outside of the pavement corresponding approximately to the addition on the inside of the pavement is little used. The natural deduction from these easily checked statements is that the widening of the pavement on ordinary curves is of relatively little importance, but that it is a matter of real importance that curves be so approached that vehicles shall have a reasonable distance within which to adjust their course to the curvature in the alignment of the road.

As a matter of fact, the reason that vehicles do not use the outside of widened curves is that, generally, there is no transition between the tangent and the full circular curve on the outer edge of curves as they are now designed. As a result the outer line of vehicles, in making its own transition, cuts in from the outer edge of the pavement, leaving the extra width practically unused. The conclusion from this is that the only widening that is required is that which is necessary to provide turning space for the rear wheels plus a small addition to satisfy the psychological demand for more passing room on curves. If, with this small additional width, carefully designed approaches were provided on the outside as well as the inside of the curves, the result would be perfectly satisfactory and there would be a distinct saving in the amount of pavement laid on each curve, the saving being in the general shape of a lune extending from the P. T. C. to the P. T. T. and having, as its maximum width, a large part of the extra width now laid on the inside of curves.

CONSTRUCTION METHODS.

The execution, in the field, of superelevation and widening requires care and skill. Indeed, an engineer should always be employed to stake out work of this character and to keep check on it during construction. Where curves are widened the widening should be made a part of the pavement and built simultaneously with the rest of the pavement.

The greatest difficulty in constructing superelevated curves occurs in the section where the crown is eliminated, and unless these sections are carefully built they are apt to be rough and the comfort of the traveler as well as the permanance of the road adversely affected. Where the crown is eliminated before the transition section is reached the elimination is generally done by eye, and both the transition and the superelevation are tended to by an adjustment of the side forms.

This method is applicable to all types of pavement. Where it is used for gravel or macadam pavements stakes instead of side forms are set both on the inside and the outside of the pavement and the subgrade prepared and the metal spread in accordance with these stakes. Of course, no very great accuracy can be secured with pavements of this type, as surfaces compacted by rolling are always somewhat wavey, but with a moderate amount of experience and with care in calculating the amount of material which must be spread in order to secure a given thickness of finished road, the results will be entirely satisfactory.

In taking out the crown, when this is done before the superelevation is begun, an allowance of 10 feet per inch of crown is ample. Where the elimination of the crown and the transition are combined this is sometimes accomplished on concrete roads by the use of false forms, and efforts have been made to use adjustable templets. The adjustable templet is ideal in theory, but in practice it has been found difficult to manipulate and has been generally abandoned. Beyond the section in which the crown is eliminated there is no difficulty. The practice of using no crown where there is full superelevation is universal and the added width offers no problem of importance. The forms can be, and indeed are, set

State practices in superelevation and easement of curves.

State.	Method of superelevating.	Pitch of fully superelevated sections.	Transition section and rate.	Complete bank.	Pavement cross section on fully superelevated section.	Extra width.	
						Amount.	Character.
California mountain roads.	.....	¾ inch per foot, 75-foot radius and under. ½ inch per foot, 75–100-foot radius. ⅜ inch per foot, 100–150-foot radius. ¼ inch per foot, 150–225-foot radius. ⅛ inch per foot, 225–300-foot radius.	Transition length 30 feet, one-half on tangent and one-half on curve, except on reverse curves, where it may be made as long as 50 feet.	.....	Uniform slope, thickness and width, except that when superelevation exceeds ¼ inch per foot and is toward the fill slope a curb 6 inches wide and 10 inches high is used on the lower edge.	2 feet on 150-foot radius and less, if pavement is less than 18 feet wide.	
Indiana.....	Revolved on center line of surface as axis.[1]	½ inch per foot width, all curves.	Outer edge raised from 2 inches below elevation of center line at P. T. C. to 4½ inches above center line at P. C. and line on inner edge, 9 feet from center line, lowered from 2 inches below elevation of center line at P. T. C. to 4½ inches below at P. C.	Full bank P. C. to P. T.	Uniform slope edge to edge, and uniform thickness, P. C. to P. T. Uniform width. P. C.+50 to P. T. −50.	8 feet for 30° curve..... 8 feet for 20° curve..... 6 feet for 15° curve..... 4 feet for 10° curve..... 2 feet for 5° curve..... 1.6 feet for 4° curve.....	Uniform width P. C. +50 to P. T. −50. Transition curves, 100 feet long.
Michigan.....	Revolved on a line near inner edge of curve parallel to center line of unwidened pavement and one-half of the normal width of the pavement therefrom.	1 inch per foot width, 66 to 150 foot radius. ¾ inch per foot width, 151 to 300 foot radius. ⅝ inch per foot width, 301 to 450 foot radius. ½ inch per foot width, 451 to 700 foot radius.	P. C.−75, normal section.... P. C.−50, ¼ normal superelevation. P. C.−25, ½ normal superelevation. P. C., ¾ normal superelevation. P. C.−25, full superelevation.	Full bank P. C.+ 25 feet to P. T.−25 feet.	Uniform slope edge to edge, and uniform thickness; variable width.	6 feet for 66 to 150 foot radius. 5 feet for 151 to 300 foot radius. 4 feet for 301 to 450 foot radius. 3 feet for 451 to 700 foot radius.	Transition and widening obtained by using simple curve of longer radius on inside of curves.
New Jersey.....	Revolved on center line of surface as axis.	⅓ inch per foot width.....	100-foot easement section.... Normal section at P. C.−100, one-half of full superelevation at P. C.−50, and crown largely eliminated.	Full bank P. C. to P. T.	Uniform slope edge to edge, uniform thickness, and uniform width.	.....	No widening.
New York.....	Revolved on center line of surface axis.[1]	1 inch per foot width up to 300-foot radius. 1⅛ inch per foot width, 300 to 400 foot radius. ⅞ inch per foot width, 400 to 550 foot radius. 1⅛ inch per foot width, 550 to 800 foot radius. ¾ inch per foot width, 800 to 1,500 foot radius. ½ inch per foot width, 1,500 to 2,500 foot radius.	Zero at 85 feet back of P. C. (300-foot radius). Zero at 75 feet back of P. C. (300 to 400 foot radius). Zero at 65 feet back of P. C. (400 to 550 foot radius). Zero at 55 feet back of P. C. (550 to 800 foot radius). Zero at 45 feet back of P. C. (800 to 1,500 foot radius). Zero at 35 feet back of P. C. (1,500 to 2,500 foot radius).	Full bank P. C. to P. T.	.....	8 feet for 300-foot radius.... 7 feet for 300 to 400 foot radius. 6 feet for 400 to 550 foot radius. 5 feet for 550 to 800 foot radius. 4 feet for 800 to 1,500 foot radius. 3 feet for 1,500 to 2,500 foot radius.	Uniform width P. C. to P. T. with transition on tangents.
Ohio.....	Inside edge of pavement kept a uniform distance, equal to crown on tangents, below grade line.	0.042 foot per foot width, 30° curve. 0.042 foot per foot width, 4° curve. 0.032 foot per foot width, 3° curve. 0.021 foot per foot width, 2° curve. 0.011 foot per foot width, 1° curve.	Transition on tangents..... At P. C.−50 feet, normal crown. At P. C.−25 feet, pavement raised one-fourth total superelevation. At P. C., pavement raised one-half total superelevation. At P. C.+50 feet, use total superelevation.	Full bank P. C.+ 50 feet to P. T.−50 feet.	Uniform slope edge to edge, and uniform thickness; uniform width, P. C.+50 to P. T.−50.	8 feet for 30° curve..... 1.6 feet for 4° curve, etc..... 0.4 foot for 1° curve.....	Uniform width P. C.+50 feet to P. T.−50 feet; transition curves 100 feet long, established by offsets.
Pennsylvania..	Revolved on center line of surface as axis.[1]	½ inch per foot width for all curves, 50 to 300 feet radius.	Spiral transition used on inside only. Rate and amount by special table.	Full bank between transition curves.	Uniform slope edge to edge, and uniform thickness, uniform width.	6.5 feet for 50-foot radius .... 4.5 feet for 100-foot radius.... 3 feet for 200-foot radius..... 2.5 feet for 260-foot radius.... 2 feet for 300-foot radius.....	Spiral transition; uniform extra width between transition curves.
Washington....	Revolved on center line of subgrade as axis.[1]	0.055 foot per foot width, 40° curve. 0.0475 foot per foot width, 20° curve. 0.035 foot per foot width, 10° curve. 0.018 foot per foot width, 3° curve.	At P. C.−50 feet normal section; at P. C. one-half of total superelevation; at P. C.+50, full superelevation transition curve on inside edge of pavement only.	Full bank (P. C.+50 feet to P. T.−50 feet).	Uniform slope and thickness; width increases to P. C.+ 150 feet, then uniform to P. T.−150 feet.	Extra width equals the cube root of the degree of curvature to the nearest one-tenth foot, the minimum used being 1.5 feet.	Zero at P. C.−50 feet. 10 per cent of total at P. C. 59 per cent of total at P. C.+ 50 feet. 87 per cent of total at P. C.+ 100 feet. Total at P. C.+150 feet.
West Virginia..	Revolved on center line of surface as axis.[1]	0.06 foot per foot width, 75-foot radius. 0.047 foot per foot width, 125-foot radius. 0.039 foot per foot width, 175-foot radius. 0.037 foot per foot width, 200-foot radius. 0.025 foot per foot width, 400-foot radius.	Superelevation at P. C. one-third total, and at P. C.+ 25 two-thirds total.	.....	Uniform slope edge to edge, and uniform thickness.	3 feet for 75-foot radius..... 2 feet for 125-foot radius..... 1 foot for 175-foot radius..... 0 foot for 200-foot radius..... 0 foot for 400-foot radius.....	Widening to be done by "mooning" on inside of curve.

[1] "Center line" referred to in Indiana, Pennsylvania, New York, Washington, and West Virginia is the center line of the unwidened curve, and not the center line of the curve after widening.

to the established grade and concrete manipulated as on other parts of the work except that, even though a machine finisher is used on other parts of the work, hand methods of finishing have to be used on the curves.

STATE PRACTICES IN SUPERELEVATION.

Although not all of the State highway departments have established definite standards for the superelevation and easement of highway curves, a sufficient number have outlined their practice in their plans and specifications so that a general survey is possible. The table on page 11 gives this information in brief and shows the method of obtaining superelevation, the pitch of the totally superelevated section, the length of transition section and the rate of transition, together with the amount and character of the extra width of pavement used in connection with superelevation for the States listed.

METHOD OF SUPERELEVATION.

As previously pointed out, the superelevation is accomplished by revolving the pavement on the center line as an axis or on the inside edge as an axis. A glance through the table indicates that the first method is the one most commonly adopted. This is as might be expected, for under this practice the center-line grade is not distorted and there is no appreciable modification in the quantity of earthwork which must be handled.

THE PITCH OF FULLY SUPERELEVATED SECTIONS.

The pitch of fully superelevated sections varies considerably. In Ohio the maximum rate of superelevation, which applies to all curves of four degrees or sharper is one-half inch to the foot. In New York a pitch of 1 inch to the foot is used where the radius is 300 feet. In Michigan the same pitch is used for a radius of 150 feet or less. Practically all of the States vary the amount of superelevation as the radius of curvature varies. In this regard, as in the amount of superelevation used, the New York State practice deserves special study. By comparing the New York practice with the rates of superelevations and the radii shown in figure 2, it will be observed that the New York practice furnishes complete superelevation for a speed of 20 miles per hour on curves of 300-foot radius, and a complete superelevation for a speed of 30 miles per hour on curves having a 1,500-foot radius.

Speaking generally, the protection offered on curves whose radii lie between these limits is from 20 to 30 miles per hour. Speed limits in New York State are somewhat higher than in most States, but these facts serve to indicate that the policy in New York is to superelevate highway curves so that the traffic will be almost completely protected within the legal speed limits except on curves which are so short that drivers would normally choose lower speeds.

TRANSITION SECTION AND RATE.

In the matter of transition, as in other matters, State practice varies considerably. The length of the transition section should be such that a car moving at the legal rate of speed, say 25 miles per hour, can be comfortably diverted from the tangent to the full curve within the transition section. As a speed of 25 miles per hour is equivalent to a speed of 36 feet per second, it can be readily seen that transition sections of some length are necessary. In Ohio the transition section is 100 feet long without reference to the radius of the curve to which it is an approach. Other States generally follow a similar system. Indeed, it is only in New York State that the length of the transition section is a function of the radius of curvature. Logically, is takes longer to divert a car from a tangent to a curve of 300-foot radius than to a curve of 2,500-foot radius and this fact has been recognized by the New York authorities to the extent of requiring an 85-foot transition section in the first case as against a 35-foot transition section in the second case.

FULLY SUPERELEVATED SECTIONS.

Without exception the States which superelevate use a uniform slope from edge to edge and a uniform thickness where curves are fully superelevated. The thickness of the pavement varies from project to project in many States, and as traffic conditions change, in all States. Therefore, no definite statement as to thickness can be made. In general, however, the practice is to use a thickness on the superelevated sections equal to the edge thickness on the tangent plus one-half of the crown on tangents.

EXTRA WIDTH OF SURFACE.

There is as much variation in regard to the widening of curves as in regard to any other matter. As stated above, the widening of a curve has the effect of flattening the path used in driving, which is equivalent to lengthening the radius. If the transition is carefully worked out widening can be legitimately omitted except under the circumstances previously discussed in this article as applying principally to curves of very short radius. Thus in West Virginia no additional width is used where the radius is 200 feet or greater and a maximum additional width of 3 feet is used where the radius is 75 feet. This is only the amount necessary to take care of the failure of the hind wheels of an ordinary vehicle to track with the front wheels increased by a reasonable margin of safety and is based on the assumption that where the approach to a curve is properly designed and the curve is liberally banked, this is all that is necessary.

On the other hand, from this very conservative and technically accurate position there is considerable divergence in other States. The maximum diverg-

[Concluded on page 18.]

TNT A SUCCESS IN ROAD WORK

By LUKE E. SMITH, Superintendent of Road Construction, Bureau of Public Roads.

AFTER using 200,000 pounds of War Department TNT in road construction, the writer considers it the best all-around explosive for road work, and believes that when it is thoroughly understood it will produce the best results in any kind of work where blasting is necessary.

It is the safest of explosives to handle. Though it is advisable not to handle it without gloves, it has been observed that the majority of powder men soon discard the gloves, and no bad effects are experienced. This practice, however, is discouraged in the use of any blasting powder.

Though water decreases its efficiency, it does not seriously affect it unless it is exposed until it becomes thoroughly saturated. Good results can be secured in wet ground if holes are not left loaded too long.

Large quantities of it have been used in the National Forest road work of the Bureau of Public Roads and its value has been tested in a number of classes of work. We have learned that good results can be obtained in practically all sorts of work, but to obtain the best results the methods of use must be adapted to the peculiar characteristics of the explosive.

METHODS USED IN GRUBBING.

For use in blasting stumps up to 1 foot in diameter it has been found that a single charge under the center or against the tap root is sufficient. The size of the charge, however, must be varied according to the nature of the ground, and as this varies according to locality and even in different sections of the same road, no hard and fast rule governing the amount of the charge can be laid down. In blasting large stumps it is generally necessary to put charges under the main roots as well as under the center. The important thing to remember is that all charges should be well up against the stump and well covered and tamped. Under such conditions it is most convenient to explode the charge with a battery. But if a battery is not available, the following method can be used. Prepare each place for the major charges under the stump; then from these prepare a small connecting trench. Next load the holes and connect them with runs of TNT about as large as a seven-eighths-inch stick of dynamite laid in the connecting trenches. Cover all with fine dirt and make sure that no air gets to the charge in any place. A No. 8 cap and fuse in any one of the major charges will produce complete detonation. The only objection to this method of loading is the possibility of not getting the entire charge tamped so that it is air-tight. It has been found that an excellent way to confine TNT in stump shooting is to use tin cans as containers. They are much better than any kind of tamping bag for pot-hole shooting.

21591—21——3

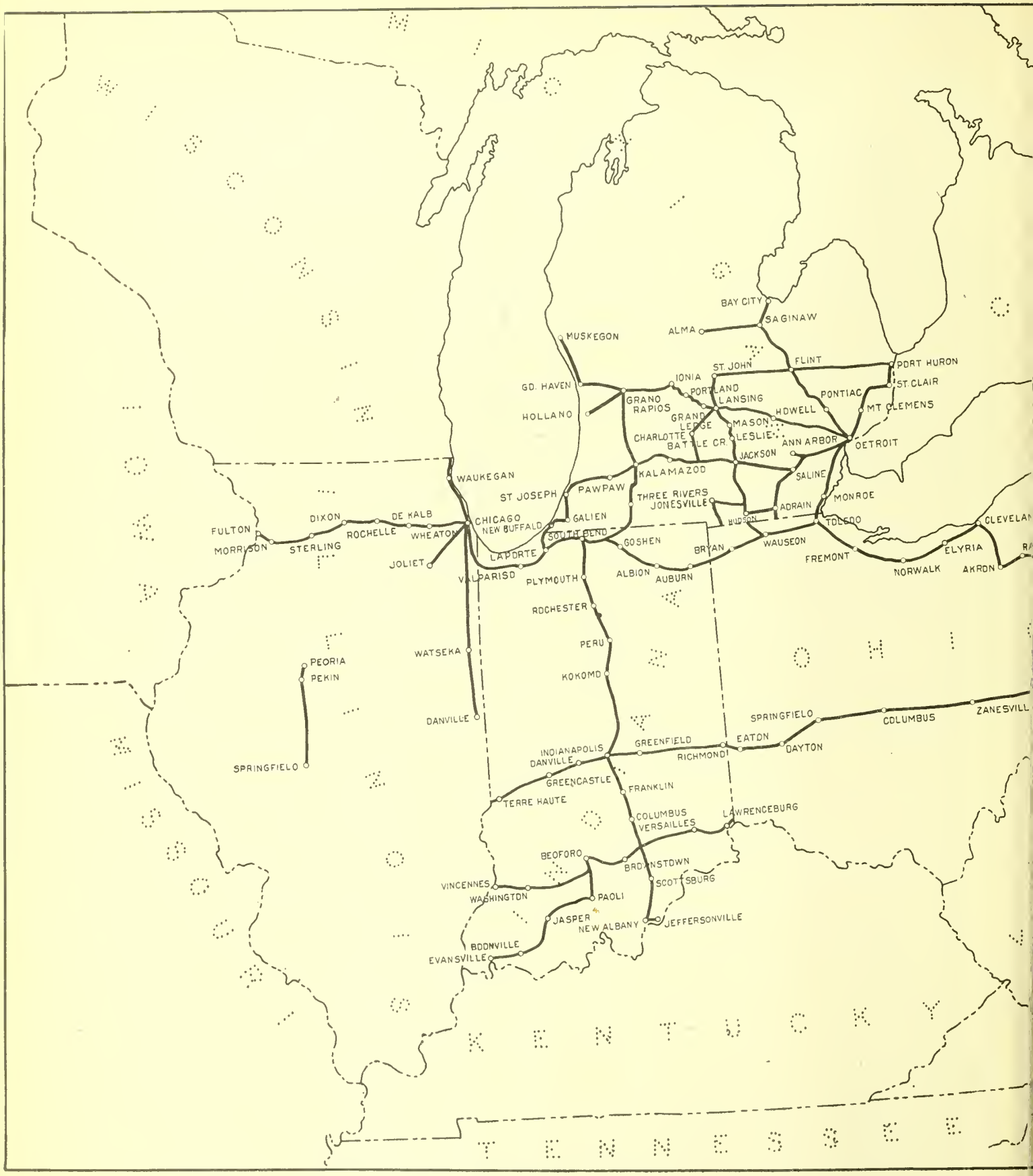
CHEAP DITCHES AND DRAINS.

A great deal of labor can be saved and costs greatly reduced on nearly all classes of work by using TNT to form ditches and drains. The single precaution to be observed to assure success is to keep the charges dry. By using tin cans as containers for the TNT and sinking them at uniform distances the charge will be kept dry even when the ditch runs through wet ground, and a complete ditch will be formed with a minimum of labor. In this case, as in stump blasting, the size of the charge should, of course, be altered with the character of the ground and the size of the ditch desired.

THE BEST EXPLOSIVE FOR ROCK WORK.

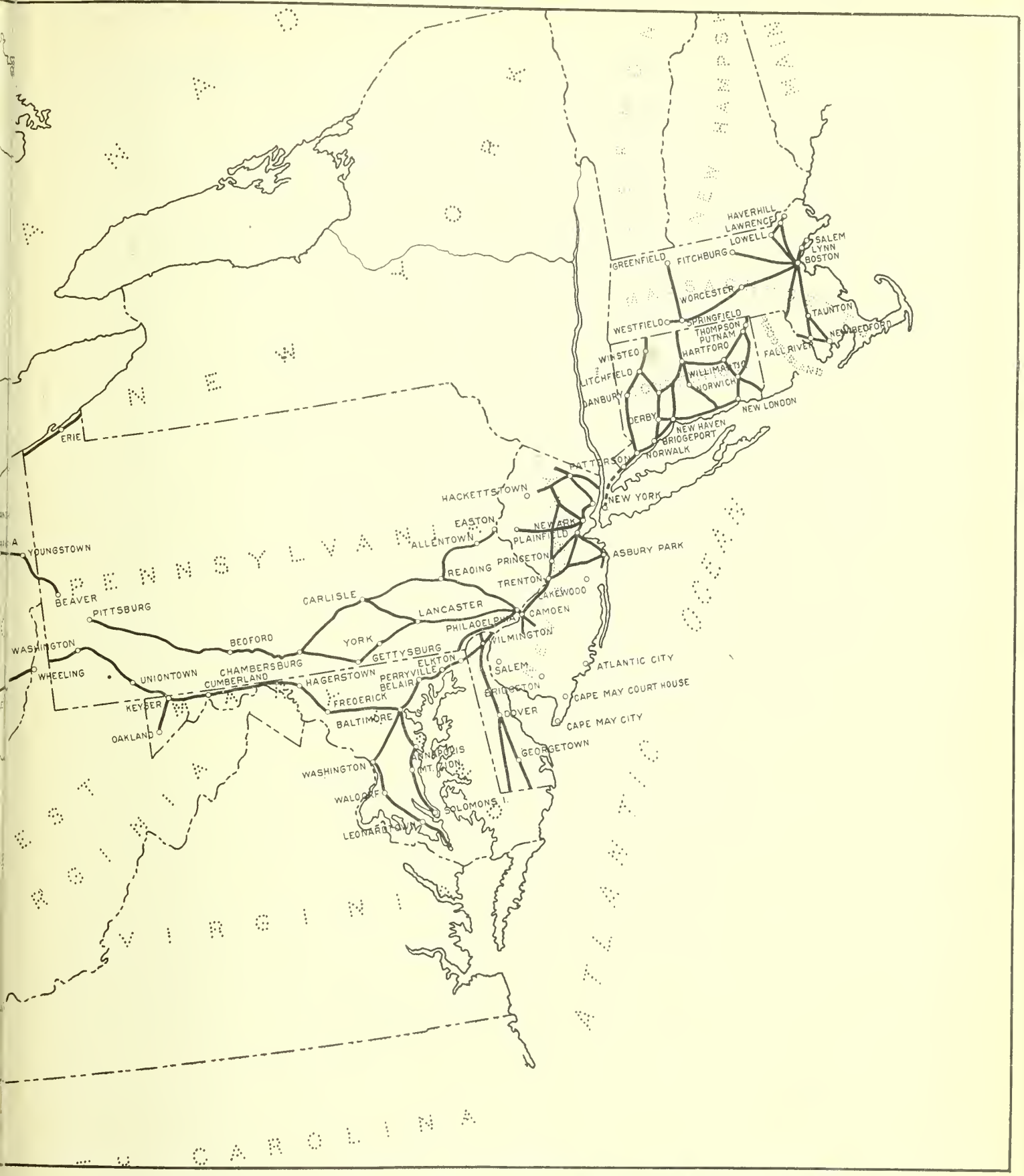
The results of TNT in rock blasting are so far superior to those of any other explosive that we have found that an experienced powderman who has once used TNT can hardly be induced to use anything else. Used in drill holes the results are better beyond comparison than can be obtained with 40 per cent dynamite, regardless of the nature of the rock. All that is necessary is to vary the size of the charge according to the hardness of the rock and the amount of excavation per hole. In extra hard rock it is the best explosive that can be used to spring holes. In springing soft material it has been found advisable to insert a section of gas pipe into the hole long enough to extend to within 1 foot of the bottom, then load the spring charge and fire. The gas pipe keeps the hole from crumbling and the TNT is quick enough to compress the walls of the chambers, which seldom ravel. The success of this practice, however, depends on the skill of the powderman. For crevice blasting TNT has no equal. It exerts a greater moving force than black powder. It seems to have greater shattering power, especially in a downward direction, than other explosives, because its quickness causes the rock to break across the seams without following them.

In some of the work of the bureau the use of TNT has made it possible to dispense with drilling machinery. It has been found that a small charge placed in the slightest depression in the hardest kind of rock will open a pocket or crevice into which a good charge can be placed which will produce the best results. In moving rock by this method during the past season 2 pounds of TNT per cubic yard were used on one project. At 50 cents per pound the cost of the explosive for this work would be $1 and with other supplies the cost per cubic yard would be about $1.10. Comparing this method with the use of drills, the average charge used per cubic yard in drilled rock is 1 pound; the cost of blasting would therefore be about 55 cents per cubic yard. At the present scale of wages, figuring 40 feet per machine per day, drilling costs 87 cents per cubic yard on many of the forest roads on account of their inaccessibility and high transportation costs and the extreme hardness of much of the rock. The comparison can be readily made with this data; the cost is $1.10 without drilling and $1.42 if the rock is drilled. The use of TNT instead of drilling saves 32 cents. Under other conditions the saving would not be so great with TNT valued at 50 cents per pound.



THESE ROADS TO BE CLEARED OF SNOW

Notes: Beaver to Pittsburgh, Pa., practically continuous city street
Philadelphia to Delaware line, a toll road



ACCORDING TO STATE HIGHWAY DEPARTMENTS

THE HOW AND WHY OF TRUCK IMPACT

By Earl B. Smith, Senior Assistant Testing Engineer, Bureau of Public Roads.

THE impact forces brought to bear on modern highways by heavy motor trucks have for some time occupied a large share of the attention of highway engineers. The study of these forces, their amount and character and the more accurate determination of their effect on highway sufaces is one of the major subjects under investigation by the division of tests of the Bureau of Public Roads.

Previous articles in this magazine have reported the progress which has been made in determining the intensity of such forces, and later articles will enter more fully into this phase of the subject and add to the large body of test data which is rapidly developing. In addition to the intensity of the forces themselves, it is highly desirable to investigate their effect on the road surface. For the lack of a better method of expression the results of the tests conducted by this bureau have been recorded in terms of "equivalent static load." Though this will suffice for the present, it is very probable that some better measure of the effect of impact must be obtained before it will be possible to design roads in a thoroughly rational manner. That the effect of impact is not the same as the effect of equivalent static pressure is a matter of common observation. Everyone has observed that steady pressure applied to a pane of glass will splinter and break it in many directions, while a high velocity bullet directed against a similar pane will pass through it leaving a small hole in an otherwise uninjured pane. This effect is now receiving the attention it has long deserved, and the results thus far obtained in the tests which are under way encourage the belief that possibly we shall be able to account for the difference between impact and static pressure.

It is not the intention of this article to enter into a discussion of these subjects, but simply to present a brief analysis of the action of the various parts of the motor truck as it passes over the road, and of the effect of the several parts in producing impact and pressure forces which are applied to the road through the wheels.

FACTORS WHICH PRODUCE IMPACT.

The impact which results when the moving truck strikes an obstruction on the road or passes over such surface irregularities as waves, potholes, and joints, is a function of several factors, most of which originate in various parts of the truck. These factors are: The sprung weight, or all weights and loads above the springs; the unsprung weight, which includes wheels, tires, axle, springs, and all other effective weights under the spring; the kind and condition of the tire; the spring characteristic which is its deformation or deflection under different loads and its period of vibration; the horizontal speed of the truck; and the character of the road surface, involving the size and shape of the obstructions or irregularities over which the wheel passes.

To deal first with the last-named factor, the irregularities and obstructions presented by the road surface must share responsibility with the irregularities and defects of the tires as the prime cause of whatever impact is produced. Given a perfectly smooth road surface, traveled by a truck with perfectly smooth circular tires, and there would be no impact, regardless of the truck's weight and speed. But since perfect smoothness of either road or tire is a condition it is practically impossible to attain, it follows that impact must be recognized as an inevitable force and its destructive effects may be reduced by proper design of the road and the truck.

In general, the effect of increasing the horizontal speed of the truck is to increase the impact. The belief formerly held that the impact would vary as the square of the speed is not borne out by careful investigation. In the tests made thus far it has been observed that the intensity of the impact has varied with some power of the speed, but this power is less than two and may be as low as one. Indeed, under some conditions, as when the truck is projected over the edge of a horizontal section of pavement and falls to a lower section the impact may be practically independent of speed.

The factors of speed and surface and tire irregularity may be regarded as the factors which create the conditions resulting in impact. The quality of the impact and the intensity of it are naturally affected by the relations of sprung and unsprung weight, the character of tires, and the characteristics of the spring used in the design of the truck itself.

Since impact is the force resulting from a mass being moved or brought to rest with a certain acceleration, it is greatest when "mass times acceleration" is a maximum. Whatever adds to mass or acceleration tends to increase impact and whatever is done to reduce mass or acceleration will tend to decrease impact.

THE EFFECT OF THE SPRINGS.

In dealing with motor trucks the total mass is really made up of two masses which are separated from each other by a spring. If the whole mass falls free from some considerable height (that is, several feet) its net acceleration will be that of gravity, but the negative acceleration at the moment of impact will not be the same as if the truck were a single solid mass. This is the result of the cushioning action of the springs which reduce the deceleration of the sprung parts. In this

case the sprung parts really do not add to the impact of the unsprung parts, but rather produce intensified pressure a moment after impact when the spring deflection reaches the maximum. This action of the spring has simply reduced the deceleration of a part of the mass and thereby decreased the impact effect from what it would have been if the whole acted as a single rigid mass.

Now, let us suppose that the truck be supported at a height of only 3 inches above the road instead of several feet as in the former example, and suppose that the deflection of the spring under the weight of the part of the mass above it is greater than 3 inches. If, then, the whole mass is dropped by releasing that part of the mass under the spring this unsprung mass will be accelerated downward by the combined effect of gravity and spring pressure with the result that it will have a very high velocity and be brought to rest very suddenly upon striking the pavement. This downward velocity and final deceleration may be very much greater than could be obtained by a free fall from a height of several feet. In this case the sprung mass has dropped very slightly but the initial compression of the spring has increased the velocity of the unsprung parts and thereby increased the impact produced by those parts.

Again, suppose that instead of supporting the truck at a height above the road which is less than the spring deflection, it is supported at some height somewhat greater. Now, if the unsprung weight be suddenly released, the whole mass drops but the unsprung parts by virtue of the propulsion of the spring will at first be accelerated faster than the mass as a whole. Then if the drop is sufficient to permit the spring to reach the limit of its oscillation before the wheels strike the road, the effect will be to decrease the velocity of the unsprung parts, relative to the whole mass, by the reverse action of the spring. In this case the action of the spring may actually serve to reduce the impact of the unsprung parts.

Thus it is seen that the springs of a motor truck tend to reduce the impact of the truck as a whole by reducing the vertical deceleration of the sprung parts; that under some circumstances they may reduce the velocity of the unsprung parts, but that under most actual conditions they may tend to increase impact by adding to the velocity of the unsprung parts. Their effect upon the impact in any case, is through the modification of the deceleration of the sprung and unsprung portions; this effect on the unsprung portion being due to a change in the vertical velocity at the beginning of impact.

THE EFFECT OF THE TIRES.

Having analyzed the action of the spring in this way, let us now examine the effect of the tires. The tires are designed to do for the unsprung parts what the spring does for the sprung parts, i. e., to reduce their vertical deceleration. The extent to which they accomplish their purpose depends upon their ability to deform or yield under the blows of the truck above them. The harder they are the greater will be the acceleration or deceleration of the truck mass, and the less will be their effect in reducing impact. A wheel tired with hard rubber, upon striking an obstruction on the road surface will produce relatively great impact, because it is only slightly cushioned by the tire, and is brought to rest in a very short space of time. If the same wheel be fitted with a softer tire the impact will be smaller, and its value will be a function of the deformation of the tire. Herein lies the advantage of pneumatic over solid rubber tires.

THE TRUCK IN MOTION.

In the foregoing discussion the action of the springs and tires has been studied under conditions of free fall from an initial state of rest. The question which will naturally arise is, do these conditions pertain to the action of the truck when it is moving over the road? What actually happens when a truck moves over a road? In the first place, the wheels are continually rising and falling as they encounter obstructions or irregularities in the road surface. At the same time the tires are alternately in a state of compression and release. The unsprung parts follow the wheels, rising and falling more or less sharply according to the kind and condition of the tires. The motion of the unsprung parts is transmitted to the sprung parts through the spring which oscillates up and down under the repeated blows of the axles. Such is the effect of the springs, however, that the motions of the sprung parts are much less abrupt than those of the unsprung parts. Their rising and falling occupies a longer period, and because of this difference in the period of oscillation, at any instant the sprung and unsprung parts may be rising or falling together or the one may be rising while the other is falling.

The movement of the sprung parts when the wheel strikes an obstruction is comparatively slight at the instant of striking. Their period of vibration, because of inertia, is rather long in comparison to the period of the unsprung parts. The displacement or maximum movement of the sprung weight occurs at some time after the impact, and produces intensified road pressures, which may be greatly more than the total load of the truck.

The unsprung parts act in an entirely different manner. When the wheel strikes an obstruction in the road it acquires an upward velocity depending upon the height of the obstruction and the speed of the truck. The reaction on the road surface is a force depending for its value upon the maximum vertical acceleration of the wheel, the mass of the unsprung parts and the spring pressure. The wheel may continue to move upward even after passing the obstruction, until the movement is overcome by spring

pressure and inertia. It is then shot downward by the combined action of gravity and spring pressure, and thus produces another impact on the road surface. The vertical reaction of this upward movement of the unsprung parts serves to retard slightly the fall of the body or sprung parts of the truck, and when this body does fall it is partially cushioned on the spring, and does not really produce an impact; but it does produce an additional pressure on the road surface somewhat like that of a suddenly applied load, which, as mentioned above, may be greatly more than the weight of the truck.

It will readily be seen that the magnitude of the impact as the wheel passes over obstructions is dependent upon the speed of the truck. It is the unsprung weight and the value of the spring pressure which produces the actual impact. The greater the spring pressure and the greater the unsprung weight the greater will be the impact. The movements of the sprung weight do not actually result in impacts, but in intensified pressures. As a factor in producing spring pressure, however, the sprung weight does add to the impact of the unsprung weight.

From these statements it may be seen that while the weight of the unsprung parts is a direct factor in the resulting impacts on road surfaces, it is not necessarily true that the heavier unsprung weights produce always the greatest impact. On the contrary, conditions may be such, with a light unsprung weight, on hard, nonresilient tires, under the influence of large accelerations or decelerations, that high impact values will be produced. It should be noted that this discussion of the effect of unsprung weights applies only to impacts on road surfaces and not to the effects produced on the truck itself.

THE EFFECT OF MASS.

Up to this point the attention has been centered upon the parts of the truck which affect impact through their effect upon the "acceleration" factor. The springs and tires reduce impact by reducing acceleration. It is obvious that the only other means of reducing impact is to reduce the mass of the truck, or since the impact is delivered through four wheels, to reduce the mass on any wheel or pair of wheels. In this direction lies the possibility of a considerable further reduction of impact, because motor trucks, as now designed, generally carry the larger part (up to 90 per cent) of their weight upon the rear wheels. In the average heavy truck the body is nearly balanced upon the rear axle. Normally a small amount of the carried load goes to the front wheels, but so near is the balance on the rear axle, that a slight eccentricity of loading will often result in decreasing the load on the front wheels. The effect of the truck upon the road surface depends upon the impact delivered by its heaviest wheel. It follows, therefore, that a substantial reduction in the destructive effect of the truck can be made by distributing the load more uniformly to the front and rear axles, thus reducing the load on the rear wheels.

This change alone would go far to reduce the heavy burden laid upon the public in the shape of repair bills for roads damaged by motor trucks. What else can be done? Roads can be kept smoother by better maintenance, though in the nature of the case they can not be kept so smooth as to eliminate impact entirely. Solid rubber tires can be kept in better repair, or better still, abandoned in favor of cushion or pneumatic tires wherever possible. Operating speeds can be kept within reasonable limits. Such measures will reduce the intensity of the destructive force. Whatever impact remains when these things have been done is the force which it is the duty of highway engineers to provide against in the design of future highways.

SUPERELEVATION AND EASEMENT AS APPLIED TO HIGHWAY CURVES

[Concluded from page 12.]

ence is in the State of New York where an additional width of 3 feet is allowed on curves having a radius of 2,500 feet, which additional width is increased by stages until for a radius of 300 feet an additional width of 8 feet is used. Unquestionably this adds something to the safety with which curves can be used by fast moving vehicles, but it also adds considerably to the cost of construction and under ordinary circumstances, that is, where both safety and expense must be considered, a combination of the New York standards as to the amount of superelevation and the West Virginia standards as to widening with a liberal allowance for transition distances will probably prove to be as safe as any solution which can be devised and as cheap.

SUPERELEVATION OF REVERSE CURVES.

Ohio specifies that, where possible, reverse curves shall be separated by tangents at least 100 feet in length. On short curves, where this is impossible, the cross-section is made level at the point of reverse curve and the superelevation gained in a distance of 100 feet in each direction. Mr. G. A. Curtis, district engineer of the Massachusetts Highway Commission, suggests that 30 feet of transition should be allowed for each one-fourth inch change in pitch. Thus the change from one-half inch pitch per foot of width to a full reverse of one-half inch pitch per foot of width would require the same distance as to reach a superelevation one inch per foot of width, that is, 120 feet. Where parabolic curves or spiral transition curves are used an intervening tangent, though desirable, is not as necessary as it is in most of the prevailing designs.

DESIGN AND CONSTRUCTION OF BRIDGE FOUNDATIONS

By Llewellyn N. Edwards, Senior Highway Bridge Engineer, Bureau of Public Roads.

IN view of the rapidly increasing demands of traffic upon our highways the design and construction of new bridges should involve provisions not only for existing conditions but also for those which may reasonably be expected in the future. Naturally enough we can not plan intelligently for the future unless we can foresee the conditions with which we will have to deal; we can not create efficient designs unless we have a knowledge of the future demands as to capacity and sustaining power. However, all will agree that careful surveys of service requirements both immediate and future will assist in the making of well developed guesses.

REINFORCED CONCRETE ARCH BRIDGE WRECKED BY STREAM SCOUR. AS CONSTRUCTED, BRIDGE HAD SHALLOW FOUNDATION ON GRAVEL. WATERWAY APPROXIMATELY 50 PER CENT THAT REQUIRED.

Speaking generally, a bridge structure consists of three portions or parts, viz:

(1) The superstructure or spanning portion supporting, in addition to its own weight, pedestrian, vehicular, and other so-called "live" loads.

(2) The substructure supporting the superstructure with its loads, and,

(3) The foundation which supports the substructure with its superimposed loads.

Obviously the stability of the entire structure depends primarily upon the efficiency of its foundation. However, it may be said without fear of contradication that science, skill, and experience combined with the progress of the time have achieved marked success in evolving the rationale of bridge design and in producing and developing new types of superstructures and substructures, while a far less degree of attention has been bestowed upon the development of fundamental principles and reliable information and data relating to the bearing power of soils, and to methods and operations involved in the design and construction of foundations.

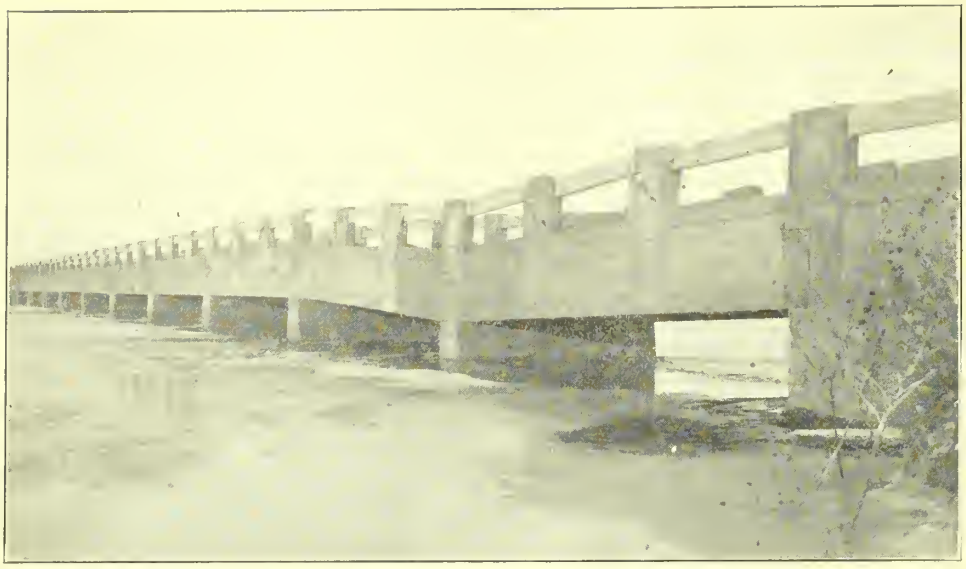
In this connection it is especially important to note that a very large percentage (probably 70 per cent or more) of bridge failures are primarily due to unsatisfactory foundation conditions. The money value involved in these failures is, to say the least, unfortunate but quite apart from this, the inconvenience and economic disadvantages incident to the tying up of traffic by failures, and the moral responsibility attached to the construction and maintenance of structures menacing human life demand full consideration.

CONDITIONS AFFECTING STREAM SCOUR.

With an occasional exception, the construction of bridges over streams has the effect of obstructing free stream flow by contracting the channels and by producing eddies, cross currents, whirlpools, etc., resulting in accentuating any tendency that may exist to erode or scour the beds during periods of high water. The location and extent of scour is mainly dependent upon the courses of the streams, the rate of their currents, and the character of the soils forming their beds. The greatest scour will generally take place in the vicinity of the portions of the structure furnishing greatest resistance to the free flow of the water. In general, piers and abutments should have their foundations located well below the range of possible scour. However, to render them secure against unforeseen eventualities they are often protected by the installation of riprap, stone filled cribs, brush mattresses weighted down with large stones, concrete aprons, etc.

ADEQUATE FOUNDATION SURVEYS IMPORTANT.

In general, the loads considered by the designer, in proportioning bridge pier and abutment footings are (1) the total dead load of the superstructure and substructure, (2) the live load including under certain



PIER FAILURE RESULTING FROM STREAM SCOUR. SAND OF RIVER BED "ALIVE" AT HIGH-WATER STAGES. PILES IN FOUNDATION HAD INSUFFICIENT PENETRATION.

conditions an allowance for impact, and (3) earth pressures in the ease of abutments aeting as retaining walls. To the foregoing may be added (4) forces induced by temperature in the case of piers and abutments for arch spans, and (5) wind, ice, or other external pressures in exceptional eases. In the absence of definite data as to the bearing value of the foundation this refinement of load ealeulation would be of no advantage. It is therefore of basic importance that the designer be in possession of all available information relating to foundation conditions. The seeuring of this information necessarily involves a survey of soil conditions by making borings, sinking test pits, driving test piles, etc., to discover subsurfaee conditions. It also involves a general survey to obtain data relating to the size of the drainage area, rate of stream flow, direetion of stream currents. high and low water elevations, possibility of aceumulations of drift, etc., likely to affeet stream seour, together with a contour survey of the bridge site.

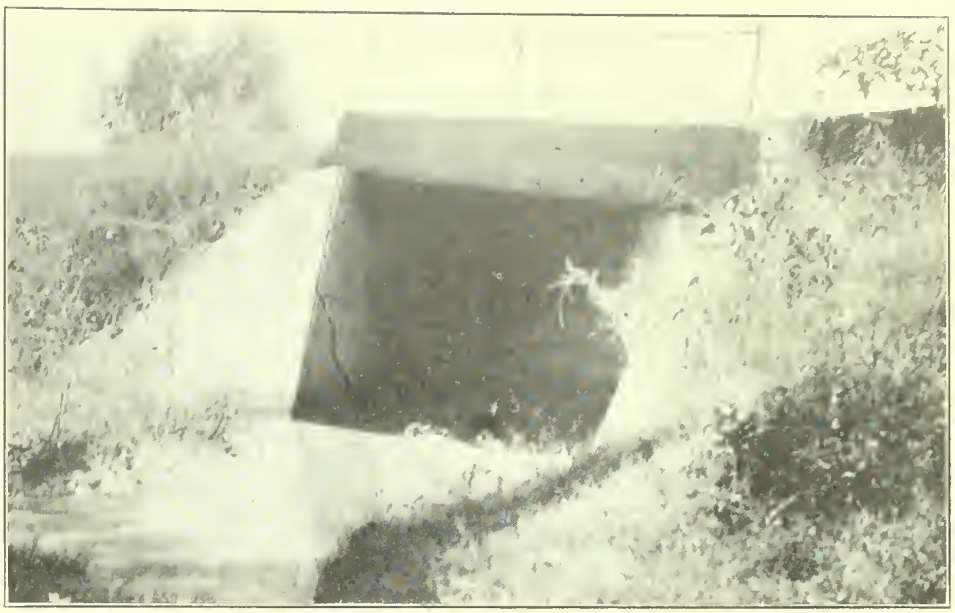
The general formation, density, and thickness of strata of soil vary so much that the testing of the foundation soil and the depth of underlying strata are absolutely necessary for the determination of the allowable pressures that may be placed upon the foundation material. The course, depth, and velocity of the stream in the vicinity of the bridge site, together with natural conditions influencing the future development of surrounding property, should receive full consideration in their relation to stream currents and scour of the stream bed.

Too frequently survey plans provide insufficient information for the preparation of the design and the working drawings of bridge structures. The character of the foundation materials is too often assumed to be the same as that showing upon the surface at the bridge site. Occasionally the superfieial examination of the soil is primarily due to the fact that the equipment of the survey party does not even inelude a mud auger with which to make the simplest kind of a subsurfaee examination. However, there are other faetors which sometimes enter into the field survey work. The observer, not realizing the importance of aeeurately describing the character of the foundation soil, fails to incorporate a proper description in his field notes; or, what is even worse, the draftsman preparing the survey plan, believing that "brevity, brevity always" is a mark of efficieney, will eliminate all tendencies to verbosity and will concentrate paragraphs into single words such as "clay," "gravel," "bowlders," ete.

To emphasize the importanee of the foregoing it may be of value to cite an actual case of construction work. The bridge referred to was loeated at the outlet of a eomparatively large lake. The survey party, although equipped with a mud auger outfit, made only a surface examination of the soil and the survey plan prepared from its field notes showed "bowlders with clay" as foundation material. "Bowlders with clay" constitute under certain eonditions excellent foundation material. However, in this particular case the "bowlders" were merely "one man" stones whieh had been deposited along the river banks by ice floes. Knowing nothing of the field conditions other than was shown upon the survey plan the designer assumed a foundation pressure whieh seemed justified by the description and designed the substructure accordingly, placing the foundation elevation at a depth below possible frost action. When the foundation pits had been excavated to a depth of 2 to 3 feet all of the "one man" stones had been removed and the underlying blue clay was soft and altogether unreliable as a foundation material. Soundings were made with a steel bar by one of the workmen which indicated the existence of firm material at a depth of approximately 3 feet below the foundation elevation shown on the substructure plan. When the overlying clay had been removed a hard, durable limestone foundation was seeured. This material was capable of safely sustaining a much greater load per unit area than had been assumed in the original design and had conditions permitted, a eonsiderable economy eould, doubtless, have been affected by redesigning the entire substrueture.

PRESSURE DISTRIBUTION NOT ALWAYS UNIFORM.

Having discovered the character of the foundation material by a careful survey, it is important to remember that foundation pressures are not always uniform. Other conditions being equal, a pier symmetrically loaded and symmetrically shaped will produce a uniformly distributed pressure upon its foundation, but irregularities in the lengths of superstructure spans, cut water construction on the upstream end, subjection to heavy ice floes, etc., tend to produce variable foundation pressures. Abutments are commonly so located as to perform the double function of supporting the superstructure and resisting the pressure of the earth fills forming the bridge approaches. The pressure exerted upon an abutment foundation is, therefore, rarely a uniform one and in consequence, the so-called "toe pressure" is greater per square foot of foundation area than is the "heel pressure."



REINFORCED CONCRETE SLAB BRIDGE FAILURE. ALLUVIAL SOIL FOUNDATION MATERIAL. FOUNDATION INSUFFICIENT DEPTH BELOW STREAM BED.

The pressure per square foot used for designing purposes should be well within the safe bearing power of the soil; that is, a pressure which will not produce appreciable settlement. If, perchance, an undue settlement takes place, the abutment will tilt forward and may ultimately result in a total failure of the structure.

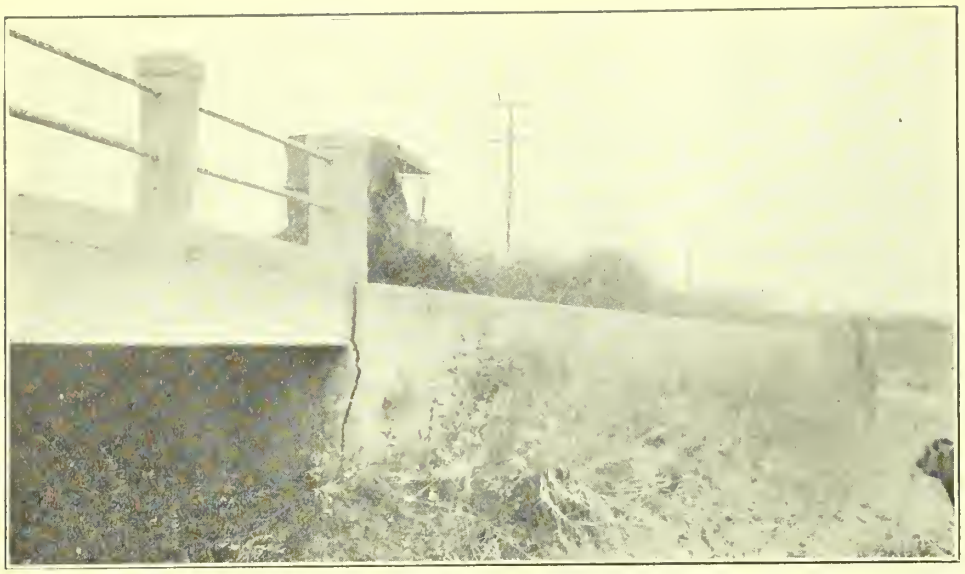
One of the distinctive advantages resulting from the common practice of building piers with battered sides and ends and abutments with battered face surfaces on the body and wings is that a slight tilting may take place without giving to the substructure an overhanging and unstable appearance. It is important in this connection to call attention to certain structural weaknesses resulting from substructure and foundation movements. Almost without exception such movements subject the superstructure to stresses for which no provision was made in its design, though the actual condition existing may not become fully apparent even by the most careful and critical examination. A pin-connected truss span gives greater evidence of the conditions mentioned than does a riveted span. By reason of a slight derangement of the correct alignment of the bottom chord pins, a portion of the eye bars become loosened, thereby rendering them partially or entirely inactive with the natural result that the stresses these bars were designed to carry are actually carried by the other bars. Structures composed of mass and reinforced concrete frequently give evidence of substructure and foundation movements, for in these structures the induced stresses appear to seek out the weakest portions and, in consequence, the resulting fractures may take most unfortunate courses and by progressive action may result in the development of very dangerous structures or possibly in failures.

Speaking generally, foundations are either natural soils, including rock formations, or artificial foundations consisting of compacted soils, soils reinforced with piles, grillages, etc.

NATURAL FOUNDATION MATERIALS.

Natural soils are an ever varying quantity, heterogeneous in their composition and stability. Their bearing power depends mainly upon the general formation, texture, density, uniformity, and thickness of the strata. A stratum composed of a soil having, under ordinary conditions, a comparatively low bearing power may be so confined by a thick, strong overlying stratum that it will sustain with ample safety a greatly increased load. A similarly placed stratum located with an outcropping in the hillsides of a deep ravine or river valley may be subject to a very slow oozing flow under the pressure of a superimposed abutment or pier, which will ultimately result in a sufficient settlement of the foundation area to produce appreciable superstructure deformations. Usually under these conditions the vertical movement is combined with a lesser movement of the overlying material, producing a horizontal displacement of the bridge structure. Such movements may involve a period of months or even of years to become fully developed. They may continue at a practically uniform rate or may become accelerated by reason of a weakening of the overlying strata, resulting from fissures, fault lines, etc., existing within them.

Natural soil foundation materials are divided into five general classes, viz: (1) Bedrock, (2) gravels,



OVERTURNING RETAINING WALL. EARTH PRESSURES ON HIGHWAY SIDE OF WALL GREATER THAN ITS RESISTANCE TO OVERTURNING.

(3) sands, (4) clays, and (5) ordinary soft soils and earths.

BEDROCK AS A FOUNDATION.

Bed rock is, as a general rule, practically secure against stream scour and under ordinary working pressures is incompressible. However, its surface may be irregular, presenting shelly areas and numerous cracks and fissures, through which water frequently flows very freely, rendering the work of preparing foundation areas costly and difficult. On the contrary, it may present a surface worn smooth by glacial or water action and rounded or tilted at such an angle with the horizontal that it becomes necessary to level it horizontally as a whole or in steps in order to render the substructure, piers, or abutments placed upon it secure against scour, sliding, etc.

The influence of the elements upon bedrock must be taken into consideration, especially when outcroppings are contemplated for use as foundations, as certain rock formations are subject to disintegration when so exposed.

The brief discussion of bedrock materials here given would be incomplete without a reference to that grade of soils which, for want of a better nomenclature, will here be referred to as "near rock." It is especially important to exercise caution whenever these materials are being considered for foundation purposes. The most common of these are:

(*a*) Soft shale, sandstone, limestone, and other rocklike material generally known as "rotten rock."

(*b*) Very compact and shale-like beds of clay which are subject to rapid disintegration when subjected to scour.

(*c*) Beds of compact clay, similar to the above, which tend to slake when subjected to atmospheric conditions.

(*d*) Beds of cemented gravel or sand which disintegrate freely when subjected to scour.

As a general rule, "near rock" soils are appreciably compressible when submitted to fairly high unit pressures and, in addition, many of them disintegrate freely when subjected to the erosive action of swift currents.

GRAVEL A GOOD FOUNDATION.

Gravel varies widely in its granulometric composition and in the original rock material of which it is composed. Gravel is not readily defined since its many uses in bridge, road, and other construction work have established for it various limitations as to maximum and minimum sizes of particles. However, a somewhat commonly accepted definition is: "Small worn fragments of rock material which will pass through a screen having holes $2\frac{1}{2}$ inches ($2\frac{1}{2}$-inch screen) in diameter and be retained upon a sieve having four meshes per linear inch (No. 4 sieve)." In so far as its use as a foundation material is concerned, the term "gravel" is very generally applied to material having approximately the above-described grading intermixed with sand.

A gravel having its particles well graded from coarse to fine and firmly cemented with a natural earthy cement containing iron, silica, lime, or other comparatively stable cementing material, if existing in a stratum 4 to 8 feet or more in thickness, is practically incompressible under the pressure produced by ordinary bridge structures and provides an efficient foundation even when overlying a less reliable substratum. Well cemented gravel will withstand the disintegrating influence of a quite rapid current. Slow disintegration may sometimes result from dissolution of the cementing medium. The cemented gravels here referred to must not be construed to mean the hardest grades of conglomerates which quite properly may be considered as bed rock, but, instead, the softer conglomerates which can ordinarily be broken up in an excavation by the use of a pickax.

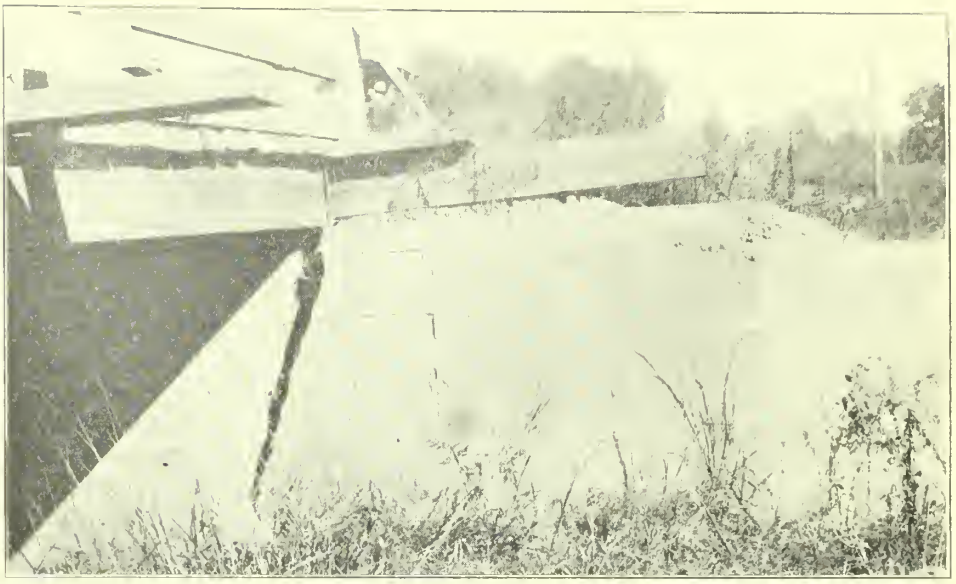
A confined gravel stratum made up of loose but well compacted material, free from the disintegrating action of water flowing through it is only slightly compressible under ordinary foundation pressures.

The illustration on page 19 shows the result of building on a shallow gravel foundation combined with a structure too short in length to serve stream requirements.

FOUNDATIONS IN SAND.

Sand, like gravel, varies widely in its granulometric composition, in its petrography, and in its other physical

properties tending to render it satisfactory or unsatisfactory as a foundation material. It may exist as a firm, well cemented, granular material practically incompressible under favorable conditions or, on the contrary, it may, when fine grained and saturated with water, exist as a soft, yielding, semifluid material quite unreliable for foundation purposes. As in the case of cemented gravel, above described, the cementing medium is commonly a natural earthy cement containing iron, silica, lime, or other cementitious material. Special care must be exercised whenever the cementing material is readily soluble in water, since its subjection to the action of flowing water would cause a disintegration of the foundation.



FAILURE OF AN ABUTMENT SUPPORTING A WOODEN SUPERSTRUCTURE. INSUFFICIENTLY DESIGNED ABUTMENT. FAILURE RESULTED PRIMARILY FROM SCOURING OF FOUNDATION.

Compact sand, thoroughly confined against lateral movement by overlying strata or otherwise, and existing in beds 6 to 10 feet in thickness, is considered an excellent foundation material, provided its stability is not endangered by a free flow of water through it. "Quicksand when properly drained makes a very stable earth, but when subjected to saturating water it becomes a hopeless mess."

Sand originally deposited by the action of water commonly exists in layers or strata varying widely in their granulometric composition. Quite frequently these strata have been deformed by subsequent movements so that they are tilted at an angle with the horizontal. A firm, well compacted stratum so tilted may be rendered useless for foundation purposes by an unreliable substratum containing an unstable loose sand, clay, or other unsatisfactory material which will fault when subjetced to foundation pressures. On page 20 is shown a pier failure resulting from a too shallow penetration of piles in a river bed composed of sand.

CLAY AN UNCERTAIN MATERIAL.

Clay may exist as a firm, unyielding material resembling shale rock, and having both cohesion and density, or on the contrary it may exist as a pasty, semifluid material having very little supporting power. This range of variation in its physical composition renders it one of the most uncertain and unreliable of foundation materials. Speaking generally, the best clay deposits of the former class are quite impervious to water and when protected from the disintegrating action of flowing water are quite reliable as foundation materials; however, it may here be remarked that some of the most dense clays are very readily scoured; also that clays giving fair evidence of stability will very frequently, through absorption of water, become less stable and compact, thus losing the important elements of a good foundation material. Not infrequently clays are encountered which, when subjected to foundation pressures, will squeeze and ooze like a firm India rubber.

"Clay even if found in hard condition is subject to slight compression, which, while uniform, may not be of much consequence." However, mention has been made above that the foundation pressures produced by abutments and retaining walls are very commonly variable from front to rear of wall, thereby tending to produce an uneven settlement. Drainage of clay foundation areas will increase their stability and bearing power.

Clay strata which have been deformed and are tilted at an angle with the horizontal are subject to possible slipping along natural cleavage planes rendering them to a greater or less degree unreliable as foundation materials. Their dependability in such cases is based mainly upon the strike angle of the formation and the physical character of the clay strata composing the general mass. In this connection, it is important to call attention to the fact that clay strata frequently contain fissures and fault lines running at random through them. An eroded hillside may expose these planes of natural weakness in such a manner as to render a hillside foundation of clay material rather uncertain as to its effectiveness.

Ordinary soft soils and earths, when considered as foundation materials, vary in relation to the proportions of sand, clay, or other firm materials they contain; however, in general these soils will support only very small foundation pressures. They are always subject to a considerable amount of settlement and should, therefore, be used only under the most unimportant structures with comparatively small pressures

per unit of foundation area. Soils containing materials which render them plastic and greasy are considered very poor foundation material. On page 21 is shown a reinforced concrete bridge failure resulting from a too shallow depth of abutment foundations in an alluvial soil. Settlement was produced by undermining of both abutments.

With the exception of bedrock, nearly all soils are appreciably compressible when subjected to ordinary foundation pressures. The amount of settlement depends upon the character of the material and the intensity of the pressure upon it. Usually the latter is expressed in tons per square foot of foundation area. Decisions as to the adaptability of natural foundation materials and the pressures they will safely sustain without undue settlement, demand mature judgment which has been ripened by personal experience and a knowledge of the results obtained by others. The amount of settlement permissible for any given case depends, to a marked degree, upon the character of the design and of the materials used in the bridge superstructure. The permissible settlement is, for certain classes of structures, the gauge by which the allowable unit foundation pressures must be measured and final decision rendered. On page 22 is shown a retaining wall "turning turtle" either as a result of improper design or excessive "toe" pressure on its foundation.

Reference has been made to the paucity of reliable data relating to the bearing power of soils. In the absence of this data we must be guided almost entirely by past experience. Safe foundation pressures for natural soils are given in Table 1. To obtain good results the use of this table should be supplemented by an examination of the foundation material in the abutment and pier pits. Otherwise its use will occasionally lead to unsatisfactory results since any table of this kind can not possibly take full account of widely varying soil conditions.

TABLE 1.—*Safe bearing power of foundation soils for ordinary structures.*[1]

Material.	Safe bearing power, in tons per square foot.	
	Minimum.	Maximum.
Rock, the hardest kinds, in thick natural beds	(2)	(2)
Granites, limestones, and sandstones, hard grades	30	40
Granites, limestones, and sandstones, etc., medium hard grades	20	30
Limestones, sandstones, shales, etc., equal to best hard-burned brick masonry	15	20
Limestones, sandstones, shales, etc., equal to ordinary brick masonry	5	10
Gravel or coarse sand, in thick beds, well cemented	8	10
Sand, medium, in thick beds, well cemented	4	6
Sand, clean and well drained, confined	2	4
Sand, clean and wet, confined	½	3
Sand and clay combined, in thick beds, well drained, confined	5	8
Clay, firm, in thick beds, well drained, confined	4	6
Clay, firm, in thick beds, wet but not saturated	2	4
Clay, soft, confined	1	2
Alluvial soils, firm	½	1

[1] Arches, cantilevers, continuous spans, large structures, and high abutments should be founded on unyielding material. Special investigations and designs should be made for such structures.

[2] Any ordinary substructure load.

ARTIFICIAL FOUNDATIONS.

Artificial foundation materials are divided into four general classes, viz: (1) Compacted soils, (2) grillage, (3) piles, and (4) cribs.

Compacted soil foundations are sometimes used for small drainage structures having comparatively low foundation pressures per square foot. They are produced by treating soft soils and earths to render them more firm and more capable of supporting foundation pressures. Two methods of compacting are in use, viz: (1) A thick, thoroughly compacted bed of sand, gravel, or broken stone is deposited upon the soft soil after excavating it to a considerable depth. (2) A quantity of sand, gravel, broken stone or concrete is forced into the soft soil.

Grillage, as commonly constructed, consists of two or more courses of wooden timbers, laid transversely to each other and firmly drift-bolted together. The timbers may be laid in close contact or they may be separated and additional strength secured by filling the spaces between them with sand, gravel or concrete. Grillage may also be composed of metal beams filled in with concrete or of concrete reinforced by rods or other metal work to give it the desired strength. In order to secure a desired foundation pressure the grillage area is usually much larger than the base area of the substructure unit placed upon it.

Piles are more commonly used than any other class or type of artificial foundation material. Their use during centuries past has proved their reliability, especially in soil foundations where excavation to a firm unyielding stratum is unattainable by reason of excessive cost or other practical considerations. Formerly wooden piles were used exclusively, but in recent years reinforced concrete piles have been used to a considerable extent. The types, sizes, methods of preparation, etc., of piles, their proper driving, and considerations entering into the determination of their safe bearing power, although directly related to our general subject of foundations, can not be satisfactorily treated within the space here available. However, it is important to call attention to some common misconceptions of the bearing power of piles.

PILES IN SOFT SOIL.

A pile driven its entire length through soft soil depends for its bearing power upon the friction existing between its surface and the soil surrounding it. This so-called skin friction transfers or imparts to the surrounding soil practically the entire load carried by the pile; the resistance of the soil under its point and the effect of buoyancy are but small in comparison with the load transmitted to it by the substructure. On account of this fact it is improper to drive piles in soft soils at close intervals. A cluster of, say, seven piles driven in close contact with each other can scarcely be considered as developing a bearing power in excess of that developed by three piles properly spaced to transmit their loads to the surrounding soil.

Piles, dependent wholly or in part upon skin friction, produce, by transmitting their load to the surrounding soil, a corresponding soil settlement. It follows, therefore, that the soil underlying the base of the substructure may, in assuming its load, settle out of close contact with the substructure base, thus becoming independent of any foundation pressure apart from that transmitted by the piles.

By a closer spacing of the piles under the toe of an abutment than under the heel it is possible to prevent the tipping of the abutment which would otherwise take place if settlement should occur. By varying the spacing a practically uniform load per pile is secured. If perchance a future settlement of the abutment should occur, this arrangement of the piles would tend to make it uniform.

Generally speaking, engineers do not consider it satisfactory to count upon the transverse strength of a piled foundation as tending to resist the horizontal thrust of arches or other structures producing pressures acting transversely to the direction of penetration of the piles. However, it is occasionally argued that the soil upon the sides of the piles opposite the direction of the pressure can be relied upon to resist that pressure. Granting that this contention is in part true, the question arises as to the extent to which this soil can reasonably be considered as acting. At best, the problem is a complex, indeterminate one. It involves such factors as: (1) To what depth below the base of the substructure shall the thrust be considered as resisted by the piles, the soil being compressible and the piles flexible? (2) Assuming the piles in adjacent rows to be staggered, are more than the two rows of piles on the side of the foundation area opposite to the direction of the thrust active in resisting it? Naturally, any pressure borne primarily by the other rows of piles will be transmitted with little, if any, loss through the intervening soil to the two rows above mentioned. (3) To what extent is the tendency of the transverse thrust effective in disturbing the uniform distribution of the skin friction element on all piles in the foundation? Considering the indeterminate nature of these problems, and considering further that a very slight movement of the superstructure upon its foundation will induce important stresses never considered in the original design, it seems wise to forego all snap judgment and to introduce battered piles in the foundation, even at a considerable increase in cost per linear foot of the piles so driven.

THE USE OF CRIBS.

Cribs, as generally constructed, consist of grillage bottom frames with box-shaped sides extending upward from them. They are very commonly built at or near the bridge site, launched and towed out to the positions where they are to be sunk. If for a given pier, the final foundation area is covered by a layer of soft soil, it may be dredged prior to placing the crib in position or, in lieu of this, the crib may be sunk upon the soft soil which may be removed by clamshell dredging or by pumping it through the openings in the grillage bottom of the crib. If the foundation area be composed of bedrock, it may be necessary to predetermine its contour and to shape the bottom of the crib roughly to fit it, thus making possible the sealing of the crib against the admission of water preparatory to unwatering it for the construction of the pier within it.

A type of construction sometimes used consists of a piled foundation topped with a wooden crib within which the substructure, pier, or abutment, as the case may be, is built. The piles after being driven are cut off at a uniform elevation that will bring the top of the crib below minimum low water and the crib is floated into its correct position and sunk upon them. Under certain conditions this type of construction is both efficient and economical.

FEDERAL AID ALLOWANCES

PROJECT STATEMENTS APPROVED IN OCTOBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	62	Talladega	23.000	Chert	Oct. 21	$332,472.03	$166,236.01
	77	Chambers	16.800	Top soil	Oct. 13	127,762.25	63,881.12
	81	Mobile	14.000	Gravel	Oct. 25	214,898.72	107,449.36
	83	Morgan	10.100	Macadam	Oct. 11	298,505.35	149,252.67
	88	Marshall	18.159	do	Oct. 16	563,266.55	281,633.27
	89	Geneva	24.190	Sand-clay	Oct. 11	170,068.25	85,034.12
	90	Coosa and Tallapoosa	13.500	Macadam	Oct. 23	367,771.25	183,885.62
	92	Macon	20.500	Gravel	Oct. 25	379,773.35	189,886.67
Arizona	41	Maricopa	6.473	Concrete	Oct. 21	200,000.24	100,000.12
Arkansas	53	Crittenden	[1] 13.730	Gravel macadam	Oct. 12	[1] 107,975.89	[1] 30,000.00
	90	Nevada	[1] 16.360	Gravel	Oct. 25	[1] 143,280.55	[1] 68,000.00
Colorado[1]	8	Rio Blanco	[1] 17.500	Grading and draining	Oct. 26	[1] 21,918.40	[1] 10,958.20
	55	El Paso	6.629	Sand-clay	Oct. 25	66,048.07	33,024.03
	97	Powers	6.669	Gravel	Oct. 23	82,647.84	41,323.92
	124	Conejos		Bridge	Oct. 25	14,987.00	7,491.00
Georgia	179	Green	2.700	Sand-clay	Oct. 13	16,529.81	5,000.00
	182	Jenkins	8.180	Sand-clay and gravel	Oct. 27	65,587.50	30,000.00
	190	Murray	2.700	Top soil and bridge	Oct. 13	20,075.00	10,037.50
	192	Bibb	2.272	Sand-clay	Oct. 21	55,941.72	5,000.00
	197	Bullock	2.250	Hard surface	Oct. 13	58,356.65	27,000.00

[1] Withdrawn or canceled.

PROJECT STATEMENTS APPROVED IN OCTOBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Illinois	17	Adams	14.390	Earth	Oct. 16	$253,737.99	$63,434.49
Kansas	20	Johnson	[1] 6.000	Bituminous macadam	Oct. 12	[1] 65,033.32	[1] 9,754.99
	36	Cherokee	[1] 7.000	Concrete	...do....	[1] 258,656.20	[1] 105,000.00
	71	....do....	3.080	....do....	Oct. 11	337,700.00	46,200.00
	72	Atchison	3.125	Earth	Oct. 27	26,400.00	6,250.00
Kentucky	43	Nelson	3.800	Bituminous	Oct. 16	110,880.00	55,440.00
	44	Trigg	10.500	Waterbound macadam	...do....	200,200.00	100,100.00
Louisiana	63	Avoyelles	31.740	Gravel	Oct. 2	647,398.24	200,000.00
	77	Rapides	7.840	....do....	Oct. 18	98,382.62	49,191.31
Massachusetts	46	Worcester	4.261	Concrete	Oct. 13	196,438.00	85,220.00
Michigan	51	Sanilac	9.304	Gravel	Oct. 26	146,863.75	73,431.87
Minnesota	22	Dakota	17.040	Earth	Oct. 18	181,345.45	90,672.72
	79	Hubbard	.....	Gravel	Oct. 16	.....	[2] 4,063.05
	80	Polk	.....	....do....	...do....	.....	[2] 24,357.40
	82	Pipestone	.....	Concrete	...do....	.....	[2] 89,420.00
	86	Aitken	.....	Gravel	...do....	.....	[2] 5,684.50
	89	Le Sueur	.....	Concrete, brick, or asphaltic	...do....	.....	[2] 86,891.85
	93	Scott	7.130	Gravel	Oct. 12	154,993.16	50,000.00
	94	Polk	.....	....do....	Oct. 16	.....	[2] 22,135.53
	97	Olmstead	.....	Concrete, brick, or asphaltic	...do....	.....	[2] 75,397.44
	99	Todd	.....	Gravel	...do....	.....	[2] 12,492.70
	109	Redwood	.....	....do....	...do....	.....	[2] 3,275.00
	113	Crow Wing	.....	Concrete, brick, or asphaltic	...do....	.....	[2] 3,789.30
	121	Freeborn	.....	Gravel	...do....	.....	[2] 22,168.25
	122	Chippewa	.....	....do....	...do....	.....	[2] 12,395.91
	126	Rice	.....	Concrete, brick, or asphaltic	...do....	.....	[2] 45,776.04
	128	Chippewa	.....	Gravel	...do....	.....	[2] 16,960.00
	130	Big Stone	.....	....do....	...do....	.....	[2] 23,739.56
	136	Beltrami	2.940	....do....	Oct. 11	13,261.60	5,000.00
	148	Hennepin and Dakota	.....	....do....	Oct. 16	.....	[2] 59,116.54
	149	Aitkin	.....	....do....	...do....	.....	[2] 4,002.00
	150	....do....	5.840	do	Oct. 13	36,5471.60	10,000.00
	155	Polk	.....	....do....	Oct. 16	.....	[2] 34,423.67
	157	Itasca	.....	Concrete, brick, or asphaltic	...do....	.....	[2] 10,513.10
	161	Wilkins	18.780	Gravel	Oct. 13	195,408.40	97,704.20
	162	Beltrami	12.000	....do....	...do....	60,060.00	20,000.00
	164	Traverse	.....	....do....	Oct. 16	.....	[2] 15,012.10
	167	Hubbard	.....	....do....	...do....	.....	[2] 23,465.36
	169	....do....	.....	....do....	...do....	.....	[2] 5,434.70
	170	Mille Lacs	17.160	....do....	Oct. 12	145,459.60	72,729.80
	171	St. Louis	1.060	Concrete, brick, or asphalt	Oct. 13	105,227.21	21,200.00
	174	Dodge	.....	Gravel	Oct. 16	.....	[2] 13,097.78
	175	Cass	11.250	....do....	Oct. 13	122,100.00	45,000.00
	176	Itasca	7.430	Clay and gravel	Oct. 11	47,004.15	10,000.00
	179	Roseau	11.050	Gravel	Oct. 12	89,628.00	35,000.00
	181	St. Louis	1.070	Concrete, brick, or asphaltic	Oct. 13	57,527.36	21,400.00
	184	Lyon	22.830	Gravel	...do....	196,006.80	29,000.00
	185	Jackson	.....	....do....	Oct. 16	.....	[2] 4,255.00
	188	Freeborn	4.930	....do....	Oct. 11	35,565.20	3,000.00
	192	Hennepin	5.490	Earth	Oct. 13	36,746.76	10,100.00
	194	Lac qui Parle	10.370	Gravel	Oct. 12	29,564.70	10,000.00
	195	....do....	8.030	....do....	...do....	21,199.20	10,000.00
	196	Martin	7.000	....do....	...do....	78,639.88	25,000.00
	197	Dakota	.910	Brick, concrete, or asphaltic	...do....	54,883.22	18,200.00
	198	Lac qui Parle	5.780	Gravel	...do....	17,166.60	5,000.00
	199	Le Sueur	9.060	....do....	...do....	81,813.60	39,072.84
Mississippi	50	Warren	5.750	Concrete	Oct. 25	296,972.50	100,000.00
	100	Washington	10.000	....do....	Oct. 16	335,585.25	100,000.00
	101	Lauderdale	8.441	Gravel	Oct. 26	97,979.75	48,989.87
	106	....do....	3.040	....do....	Oct. 25	28,981.48	14,490.74
Missouri	159	Dade	24.500	Gravel and macadam	Oct. 11	94,399.31	47,199.65
	161	Stone	49.000	Earth	...do....	137,855.00	68,927.50
	165	Daviess	7.610	....do....	...do....	41,634.56	20,817.28
Montana	17	Flathead	9.000	....do....	Oct. 13	[1] 17,600.00	[1] 8,800.00
	102	....do....	[3] 1.600	Gravel	Oct. 11	[3] 165.00	[3] 82.50
	112	Fergus	.470	Concrete	Oct. 8	48,964.63	13,650.00
	136	Teton	13.200	Gravel	Oct. 11	76,780.00	38,390.00
	141	Missoula	.....	Bridge	...do....	83,807.90	41,903.95
	142	Roosevelt	5.000	Gravel and earth	...do....	26,675.00	13,337.50
	144	Valley	18.000	Gravel	Oct. 13	118,855.00	59,427.50
	145	Lincoln	35.000	Earth	Oct. 1	224,290.00	112,145.00
	148	Valley	12.000	Gravel	Oct. 18	80,300.00	40,150.00
Nebraska	156	Hamilton and Merrick	26.800	Earth	Oct. 11	104,544.00	52,272.00
	164	Thayer and Nicholls	28.700	....do....	Oct. 21	128,144.50	64,072.25
New Hampshire	132	Strafford	.420	Gravel	Oct. 11	10,000.00	5,000.00
New York	75	Green	1.700	Concrete	Oct. 26	96,900.00	33,915.00
	80	Warren and Essex	8.300	Macadam	Oct. 11	473,100.00	165,585.00
	82	Orange	4.000	Concrete	Oct. 27	228,000.00	79,800.00
	83	Suffolk	22.500	....do....	...do....	1,061,500.00	449,525.00
	85	Rensselaer and Washington	6.200	....do....	Oct. 25	353,400.00	123,690.00
Ohio	178	Medina	2.282	....do....	Oct. 13	92,400.00	45,600.00
	179	....do....	1.806	....do....	...do....	76,500.00	36,120.00
Oklahoma	42	Osage	5.900	....do....	Oct. 11	233,049.99	116,524.99
Oregon	21	Clatsop	[1] 14.800	Asphalt, concrete on macadam base	.....	[1] 318,835.00	[1] 159,417.50
	49	Clackamas	5.700	Concrete	Oct. 27	242,783.75	114,000.00
South Carolina	65	Newberry	4.231	Top soil	Oct. 16	40,356.10	20,000.00
	90	Fairfield	5.439	....do....	Oct. 23	40,217.83	20,108.91
Texas	25	Dallas	30.000	Macadam, asphalt surface	Oct. 9	[1] 19,999.98	[1] 9,999.99
	50	Coke	18.650	Sand-clay and gravel	Oct. 28	[1] 44,836.00	[1] 20,000.00
	207	Chambers	11.350	Shell	Oct. 11	129,708.74	38,000.00
	214	Cooke	9.500	Gravel	Oct. 23	169,619.56	80,000.00
	215	Wood	4.570	....do....	Oct. 21	72,696.16	35,000.00
Vermont	21	Franklin	2.300	Macadam	Oct. 23	103,127.75	51,563.87
West Virginia	103	Tyler	4.160	Earth	Oct. 21	46,867.40	23,433.70
Wisconsin	121	Bayfield	16.800	....do....	...do....	170,820.50	57,000.00
	169	Sheboygan	5.150	Concrete	Oct. 13	222,084.81	75,000.00
Wyoming	16	Lincoln	1.929	Selected material	Oct. 11	24,722.50	12,361.25
	103	Park	.....	Bridge	Oct. 23	7,282.00	3,641.00
	106	Washakie	2.746	Selected material	Oct. 21	33,000.00	16,500.00

[1] Withdrawn or canceled.
[2] Revised statement. Amounts given are decreases from those in the original statement.
[3] Revised statement. Amounts given are increases over those in the original statement.

PROJECT AGREEMENTS EXECUTED IN OCTOBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	14	Talladega		Gravel	Oct. 11	[1] $13,866.25	[1] $6,933.12
	17	Greene		Clay or gravel	...do	[2] 24,734.10	[2] 12,367.05
	51	Russell		Sand-clay	...do	[2] 17,114.30	[2] 8,557.15
	53	Coosa		Earth	...do	[2] 879.96	[2] 439.98
	54	....do		....do	Oct. 13	[2] 460.88	[2] 230.44
Arizona	10	Maricopa		Steel or concrete	Oct. 19	[2] 5,306.84	[2] 2,653.42
	15C	Graham		Bridge	Oct. 19	43,105.37	21,552.68
	18	Cochise		Earth	Oct. 21	[2] 11,497.67	[2] 5,748.83
	19B	Yavapai	3.976	Gravel	...do	83,839.85	41,919.92
	23D	Pinal	8.664	....do	...do	156,114.53	78,057.26
	24	Coconino	15.114	Volcanic	Oct. 21	202,588.37	101,294.18
	26	Yuma	18.630	Gravel	Oct. 19	237,860.04	118,930.02
Arkansas	8	Lonoke	[3] 1.970	Waterbound macadam	Oct. 23	[3] 8,871.72	[3] 3,169.00
	35	Pulaski	8.810	Macadam and asphalt	Oct. 19	188,419.60	87,500.00
	37	Washington	14.500	Gravel	Oct. 11	32,574.74	15,000.00
	96	Poinsett	4.250	Concrete	...do	148,104.00	42,000.00
Colorado	38	Morgan	2.727	....do	Oct. 25	102,715.63	51,357.81
	40	Yuma	3.504	Gravel	...do	29,890.85	14,945.42
	52	Teller	4.884	Earth	...do	23,628.48	11,814.24
	58A	Powers	3.129	Gravel	...do	44,978.80	22,489.40
	59	Bent	9.921	.....do	...do	85,092.02	42,546.01
	74	Moffat	6.493	.....do	...do	74,953.59	37,476.79
	75	Grand	6.847	Earth	...do	21,820.56	12,410.28
	80	Routt	6.647	.....do	Oct. 27	63,715.19	31,857.59
	86	Larimer	1.347	Concrete	...do	57,686.20	26,940.00
	91A	Las Animas		Gravel	...do	[2] 13,317.14	[2] 6,658.57
	106	Routt	1.357	.....do	...do	27,980.70	13,990.35
	107	Moffat	3.970	.....do	...do	59,026.67	29,513.33
	109	Mesa	.957	Concrete	Oct. 25	48,810.25	19,120.00
	117	El Paso	.929	.....do	Oct. 27	46,522.48	18,885.80
	118	....do	2.761	.....do	Oct. 25	136,726.37	55,220.00
	128	Rio Blanco	1.799	Shale	...do	17,342.50	8,671.25
Georgia	52	Evans	13.125	Sand-clay	Oct. 19	72,272.47	30,528.29
	66	McDuffie		Topsoil	Oct. 9	[2] 6,219.94	[2] 3,109.97
	92	Wilkes	5.236	Concrete	...do	192,403.05	96,201.52
Idaho	23A	Twin Falls	11.269	Bituminous concrete	Oct. 5	553,728.26	225,386.00
	1C,D	Mitchell	6.856	Concrete	Oct. 27	384,332.83	102,840.00
Kansas	22, A to E, F to I	Finney	27.763	Brick or concrete	Oct. 6	1,817,028.37	416,445.00
	26B	Rice	5.022	.....do	...do	347,745.24	74,490.00
	37C,D,E	Montgomery	8.452	Gravel and concrete	...do	246,224.50	123,112.25
	41B	Atchison	.761	Concrete	...do	72,881.20	11,415.00
	53A, B,C,Z	Doniphan	6.103	Concrete, bituminous concrete or bituminous macadam.	...do	318,828.27	91,545.00
Kentucky	4	Carter		Earth	June 30	[1] 10,534.37	[1] 5,267.19
Louisiana	1	Rapides		Gravel	Oct. 18	[2] 39,571.76	[2] 26,971.22
	23	Lafayette	10.420	.....do	Oct. 14	131,211.33	65,605.66
	30	Allen	10,2'0	.....do	...do	119,647.66	35,500.00
Maryland	10	Montgomery	.355	Concrete	...do	[2] 21,626.00	[2] 7,100.00
	34	Anne Arundel		Gravel	...do	[2] 66,002.01	[2] 33,001.00
	39	Dorchester	2.350	Concrete	...do	77,473.71	38,736.85
Massachusetts	17	Essex		Bituminous macadam	Oct. 13	[2] 29,267.54	[2] 4,317.07
	30	Hampden	4.227	.....do	Oct. 19	151,778.00	75,889.00
	34	Worcester	1.359	Concrete	...do	66,711.15	27,180.00
	36A	Barnstable	10.690	Bituminous concrete	Oct. 13	182,695.70	91,347.85
	40	Worcester	1.011	Concrete	Oct. 19	40,474.50	20,220.00
	41	Middlesex	1.250	Gravel surface treated	...do	23,034.00	11,517.00
	43	Worcester	.638	Concrete	Oct. 13	63,801.10	12,760.00
Minnesota	28	Grant	5.680	Gravel	Oct. 5	72,349.95	36,174.97
	80	Polk	6.010	.....do	Oct. 30	63,092.00	10,000.00
	79	Hubbard	8.810	.....do	Oct. 5	57,350.04	20,000.00
	91	Kanabec	16.370	.....do	...do	162,925.92	75,000.00
	94	Polk	9.905	.....do	Oct. 11	61,465.45	10,000.00
	99	Todd	16.940	.....do	Oct. 5	88,700.33	44,000.00
	108	Grant	16.524	.....do	Oct. 25	120,397.68	43,515.10
	109	Redwood	23.320	.....do	Oct. 5	61,178.94	19,000.00
	115	McLeod	7.790	.....do	...do	66,453.22	15,000.00
	122	Chippewa	12.380	.....do	...do	98,591.11	15,000.00
	124	Isanti	6.573	.....do	Oct. 23	78,363.93	39,000.00
	126	Rice	3.720	Concrete, asphaltic concrete, or brick	Oct. 5	148,825.67	5,000.00
	128	Chippewa	14.863	Gravel	...do	140,415.82	20,000.00
	149	Aitkin	9.270	.....do	Oct. 2	50,502.65	20,000.00
	155	Polk	13.490	.....do	Oct. 11	84,788.06	11,000.00
	157	Itasca	.807	Concrete	Oct. 5	44,595.05	5,000.00
	167	Hubbard	9.020	Gravel	...do	71,648.31	5,000.00
	169	.....do	7.430	.....do	Oct. 25	44,975.01	15,000.00
	174	Dodge	3.010	.....do	Oct. 2	49,525.80	8,462.22
	185	Jackson	6.010	.....do	Oct. 25	55,271.02	20,000.00
Montana	2	Wibaux	8.773	.....do	Oct. 26	48,761.91	24,380.95
	4	Carbon	[2] 2.624	.....do	Oct. 16	[2] 66,139.21	[2] 33,069.61
	9	Madison		Selected material	Oct. 29	[2] 9,811.88	[2] 4,905.94
	12	Broadwater and Gallatin	3.310	Earth	Oct. 26	45,386.62	22,693.31
	28	Fergus	7.890	.....do	Oct. 11	68,684.64	34,342.32
	36	Powell	4.120	Gravel	Oct. 26	29,155.48	14,577.74
	53B	Yellowstone	11.016	.....do	...do	105,352.57	52,676.28
	61	Wibaux		.....do	Oct. 9	[2] 8,934.72	[2] 4,467.36
	65A B	Teton and Cascade	35.850	.....do	Oct. 16	316,090.20	158,045.10
	66	Blaine	12.660	.....do	...do	162,688.47	81,344.23
	77	Lewis and Clark	9.057	Gravel and concrete	Oct. 9	128,737.27	59,204.32
	103C	Fergus	21.760	Concrete	Oct. 16	131,345.56	65,672.78
	115	Wheatland	9.156	Gravel	Oct. 9	74,364.90	37,182.45
	1'	...do	6.250	Earth and gravel	...do	62,193.08	31,096.54
New Hampshire	15	Merrimack		Gravel	Oct. 15	[2] 5,304.15	[2] 2,652.08
	33	Rockingham		Surface-treated gravel	...do	[2] 966.06	[2] 483.03
	47	Sullivan, Merrimack		Gravel	...do	[2] 1,254.00	[2] 627.00
	41	Merrimack	1.110	.....do	...do	20,052.36	10,026.18
	45	Strafford	.750	.....do	Oct. 14	10,030.79	5,015.39
	52	Sullivan, Merrimack		.....do	Oct. 15	[1] 655.22	[1] 327.61
	55	Strafford	.550	.....do	...do	9,905.61	4,952.80

[1] Modified agreement. Amounts given are increases. Second revision.
[2] Modified agreement. Amounts given are increases over those in the original agreements.
[3] Canceled.

PROJECT AGREEMENTS EXECUTED IN OCTOBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
New Hampshire (continued)	92	Merrimack	0.500	Gravel	Oct. 9	$8,013.11	$4,006.55
	94	Cheshire	.390	do	Oct. 14	12,055.08	6,027.54
	95	do	.790	Gravel and bituminous macadam	Oct. 15	14,879.30	7,439.65
	96	Hillsborough	.410	Gravel	do	7,489.15	3,744.57
	100	Belknap	.767	do	Oct. 14	16,094.54	8,047.27
	102	Merrimack	.910	do	Oct. 13	10,095.36	5,047.68
	103	do	.340	do	Oct. 14	10,003.76	5,001.88
	104	do	.660	do	Oct. 13	9,994.93	4,997.46
	105	do	1.140	do	Oct. 9	14,097.73	7,048.86
	108	Grafton	.380	Bituminous macadam	Oct. 15		[4] 1,406.96
	114	Strafford	1.420	Gravel	Oct. 14	24,887.06	12,443.53
	115	Rockingham	1.210	Gravel, surface-treated	Oct. 13	15 039.97	7,519.98
	119	Cheshire and Hillsborough	.430	Bituminous macadam	Oct. 14	14,835.48	7,417.74
	120A	Carroll	2.590	Gravel	Oct. 15	32,645.03	16,322.51
	122	Cheshire		Bridge	Oct. 14	16,388.90	8,191.45
	123	Hillsborough	.300	Gravel	do	7,992.05	3,996.02
	124	Belknap	1.240	Bituminous macadam	Oct. 15	17,957.44	8,978.72
	129	Rockingham	1.630	Mod. asphalt	Oct. 9	28,487.25	14,243.62
	97	Cheshire	.530	Bituminous macadam	do	19,718.71	9,859.35
New Mexico	4	Valencia		Earth	Oct. 11	[5] 5,408.55	[5] 2,704.28
	12	Chaves		Crushed rock or gravel	do	[5] 19,467.69	[5] 9,733.84
	13	Valencia		Macadam	do	[2] 8,614.86	[2] 4,307.43
	24	Roosevelt		Caliche	do	[2] 18,581.83	[2] 9,290.92
	31	Sierra	3.902	Gravel	do	23,360.14	11,680.07
	33	Moro		do	do	[2] 2,906.27	[2] 1,453.14
	47	Grant		do	do	[2] 15,215.03	[2] 7,607.52
North Carolina	48A	Northampton		Sand-clay	Oct. 30	[2] 3,959.51	[2] 1,979.75
Rhode Island	2	Washington		Bituminous macadam	Oct. 28	[1] 8,800.00	[1] 4,400.00
	8	Kent	4.400	Concrete	do	232,245.75	88,000.00
	9	Washington	2.290	do	do	117,854.19	45,800.00
	10	Newport	2.030	Bituminous macadam	Oct. 26	114,111.36	40,600.00
South Carolina	6	Marion		Bridges	Oct. 23	[1] 8,349.57	[1] 4,174.78
	17	Calhoun		do	Oct. 27	[1] 1,924.38	[1] 926.19
	21	Edgefield		Topsoil	do	[2] 10,789.47	[2] 5,394.74
	25	Lexington		Sand-clay	do	[2] 70,212.97	[2] 16,019.94
	30	Pickens		Topsoil	do	[2] 7,279.00	[2] 3,639.50
	46	Kershaw		Gravel	do	[2] 489.54	[2] 244.77
	50	Dillon	19.767	Sand-clay	do	131,604.38	40,714.39
	71	York	6.515	Topsoil	do	34,899.96	14,000.00
	73	Spartanburg	12.542	Topsoil and asphaltic concrete	do	124,843.98	18,150.82
	80	Williamsburg	11.027	Sand-clay	do	164,721.08	78,588.24
	92	Union	5.327	Topsoil	do	31,486.25	7,414.19
	100	do	3.729	do	do	36,588.18	14,828.38
	104	Calhoun	.669	Asphaltic concrete	do	49,948.50	13,380.00
South Dakota	25	Brookings	11.800	Gravel	Oct. 22	132,659.56	66,329.78
	26	Kingsbury		do	do	[2] 9,653.45	[2] 4,826.73
	29	Corson	9.053	Earth and gravel	do	80,321.63	40,160.81
	31	Beadle	8.492	Gravel	do	99,394.88	49,697.44
	37	Potter and Faulk	12.940	Earth	do	72,326.21	36,163.10
	41	Marshall and Roberts	24.460	Earth and gravel	do	248,766.07	124,383.03
	55	Deuel	9.605	Gravel	do	118,447.56	59,223.78
	20A	Walworth	8.984	Earth	Oct. 21	81,387.58	40,693.79
Texas	4	Travis		Gravel, surface treated	Oct. 9	[1] 15,681.60	[1] 7,128.00
	25	Dallas	3.000	Macadam, asphalt surface	do	[3] 25,155.87	[3] 10,000.00
	26	Titus		Gravel, bitnminous surface	Oct. 4	[2] 22,762.51	[2] 20,048.70
	36	Caldwell		Gravel	do		[2] 25,000.00
	46A	Gillespie	17.631	do	Oct. 9	169,614.85	68,680.00
	48	Bosque	51.970	do	do	157,613.21	59,900.81
	53A	Jefferson	2.500	Concrete, with asphalt top	Oct. 10	115,320.41	43,000.02
	56A	do		Asphalt	Oct. 4	88,455.46	44,227.72
	56B	do	3.010	Concrete	do	[2] 19,689.85	[2] 7,687.40
	78	Freestone		Gravel and sand-clay	Oct. 20	[2] 17,875.97	[2] 8,937.98
	83	Brown	10.750	Gravel, stone, macadam, earth	Oct. 4	90,867.43	22,500.00
	85	Freestone		Waterbound macadam	Oct. 9	[2] 15,032.07	[2] 18,000.00
	87	Travis	10.000	Bituminous	do	35,816.00	16,426.50
	105	Wood		Iron ore gravel	do	[1] 19,079.41	[1] 8,750.00
	108	Kendall	5.778	Gravel, surface treated	do	48,102.90	24,051.45
	113 1 and 2	Hill		Gravel, bituminous top	Oct. 4	[4] 24,128.02	[2] 25,000.00
	125	Liberty	.332	Gravel	Oct. 9	[4] 6,382.55	[2] 2,410.65
	142	Harrison	23.243	Gravel, surface treated	do	431,064.39	200,000.00
	146	Delta	11.310	Gravel	Oct. 4	323,800.77	120,000.00
	147	Smith	24.560	Gravel and gravel, bituminous top	Oct. 9	380,769.91	190,384.95
	153	Rains	22.340	Gravel	do	269,088.99	100,000.00
	157	Galveston	1.560	Rock asphalt	do	101,369.84	30,000.00
	159	Shelby	31.512	Gravel	do	480,427.73	169,614.58
	164	Erath	31.267	Rock and clay, gravel	do	296,948.58	148,474.29
	170	Fort Bend	13.010	Gravel, surface treated	do	250,125.74	80,000.00
	174	Randall	17.030	Earth	do	28,708.22	14,000.00
Washington	42	Grays Harbor		Concrete	Sept. 20	[2] 5,000.00	[2] 2,500.00
	56	Walla Walla	3.410	do	Oct. 25	158,694.60	72,913.50
	63	Stevens	6.460	Gravel	Oct. 14	54,825.04	27,000.00
West Virginia	23	Kanawha		Asphalt, concrete	Oct. 12	[2] 23,052.00	[2] 14,280.00
	45	Putnam		Concrete, brick, or bituminous macadam	do	[2] 15,931.12	[2] 22,541.71
Wisconsin	29	Washburn and Barron		Grading, draining, and culverts	Oct. 30	[2] 7,865.78	[2] 2,621.93
Wyoming	12	Lincoln	.251	Gravel	Oct. 4	[2] 22,417.45	[2] 11,208.72
	31	Natrona		Warrenite	Oct. 6	[2] 1,431.71	[2] 715.86
	41	Crook	10.089	Selected material	do	80,245.59	40,122.79
	42	Sheridan	9.355	do	Oct. 11	106,001.28	53,000.64
	46	Laramie	25.193	do	Oct. 4	109,733.82	54,866.91
	54	Pig Horn	.639	do	do	[1] 7,839.00	[1] 3,919.50
	57	Converse	4.251	do	do	98,764.06	49,382.03
	66B	Campbell	8.958	do	do	99,262.08	49,631.04
	71	Washakie	3.131	do	do	32,241.66	16,120.83
	76	Park	4.964	do	do	52,948.83	26,474.41
	83	Sheridan	14.129	do	Oct. 8	208,177.37	104,088.68

[1] Modified agreement. Amount given are increases. Second revision.
[2] Modified agreement. Amounts given are increases over those in the original agreement.
[3] Canceled.
[4] Modified agreement. Amounts given are decreases from those in the original agreements.
[5] Modified agreement. Increase. Third revision.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
249. Portland Cement Concrete Pavements for Country Roads.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
370. The Results of Physical Tests of Road-Building Rock.
373. Brick Roads.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914.
390. Public Road Mileage in the United States, 1914. A summary.
393. Economic Surveys of County Highway Improvement.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
463. Earth, Sand-Clay, and Gravel Roads.
532. The Expansion and Contraction of Concrete and Concrete Roads.
537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests.
555 Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
691. Typical Specifications for Bituminous Road Materials.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *37. Examination and Classification of Rocks for Road Building, Including Physical Properties of Rocks with Reference to Their Mineral Composition and Structure (1911.) 15c.
*43. Highway Bridges and Culverts. (1912.) 15c.
*45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

* Department supply exhausted.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. 89. Progress Report of Experiments with Dust Preventatives. 1907.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
98. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1911.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
52. State Highway Mileage and Expenditures to January 1, 1915.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act.
72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
77. Experimental Roads in the Vicinity of Washington, D. C.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States. 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. *638. State Management of Public Roads; Its Development and Trend. 5c.
727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 5, D-12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 32 WASHINGTON, D. C. DECEMBER, 1920

LOUISIANA FEDERAL AID PROJECT No. 22—ALEXANDRIA TO CAMP BEAUREGARD

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Papers and Discussions at Highway Officials' Convention 3

Address of the Secretary of Agriculture 4

Address of the President of the Association, Paul D. Sargent. 6

Federal-Aid Accomplishments 11
Thomas H. MacDonald

The Traffic Census 16
A. N. Johnson

Federal-Aid Allowances 30

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
SUBSCRIPTION PRICE, $1.50 PER YEAR

PAPERS AND DISCUSSIONS AT THE HIGHWAY OFFICIALS' CONVENTION.

THE sixth annual convention of the American Association of State Highway Officials was held at Washington, D. C., from December 13 to 16, 1920.

Representatives of the highway departments of every State with the exception of Washington were present and took part in the interesting discussion of highway problems which developed.

One of the most gratifying features was the spirit of mutual helpfulness and harmony which pervaded the meetings. The animating purpose of all those in attendance appeared to be the fixed determination to build up for America a splendid system of highways in the shortest possible time.

Following the practice begun last year PUBLIC ROADS will devote this and subsequent issues to as complete a report of the papers and discussions as it is found possible to print. It will not be possible in every case to give the complete text of every paper, but there will be as little condensation as possible.

Resolutions adopted by the convention were as follows:

EXTENSION OF FEDERAL AID.

Whereas necessary highway improvement will be seriously retarded in every State and possibly cease in some States unless Federal aid is continued; and

Whereas such reduction or cessation would seriously affect commerce and the public welfare in all of the States:

Resolved, That the American Association of State Highway Officials, representing every State in the Union, urges strongly that Congress shall at this session extend further the provisions for Federal assistance to the States in a manner and amount proportionate to the existing needs, and accordingly strongly urges the passage by this Congress of House bill 14905, known as the McArthur bill.

FEDERAL AID FOR HIGHWAY RESEARCH.

Resolved, That we recommend to Congress that it give by suitable legislation such authority to the Secretary of Agriculture as may enable him to grant aid to the States for highway research, any sum granted to any State to be on condition that the State contribute an equal sum, the particular research agency and the scope and exteut of the research program in any State to be as mutually agreed between the Secretary of Agriculture and the highway department in such State.

SURPLUS WAR MATERIALS.

Resolved, That we recommend to Congress that it pass further legislation that will permit further distribution to the States of surplus war material and equipment suitable for use by State highway departments.

THANKS TO THE BUREAU OF PUBLIC ROADS.

Resolved, That we extend to the Bureau of Public Roads, Mr. Thomas H. MacDonald, chief, the hearty thanks and appreciation of the members of this association for the many courtesies extended to the association and the individual members thereof during this convention.

THANKS TO THE WASHINGTON HOTEL.

Resolved, That we extend to the management of the Washington Hotel our thanks for and appreciation of the courtesies extended to the association, adding very materially to the success of the convention.

ON THE DEATH OF SENATOR BANKHEAD.

Whereas by the death of Senator John Hollis Bankhead this association has lost one of its best friends and associates, who gave unsparingly of his time and energy in the furtherance of better roads for the United States: Therefore be it

Resolved, That the American Association of State Highway Officials in session at Washington, D. C., this 16th day of December, does hereby extend the heartfelt sympathies of its members to his wife and family, and the secretary is hereby instructed to convey to the family this expression of the unanimous sentiment of the association, and to tell them that the good work accomplished by Senator Bankhead will always remain a mouument to his memory in this country.

ON THE DEATH OF GEORGE W. COOLEY.

Whereas the Hou. George W. Cooley, former State engineer of Minnesota and one of the original members of this association, has completed his work and passed beyond since our last meeting: Therefore be it

Resolved, That the American Association of State Highway Officials in session at Washingtou, D. C., this 16th day of December, does, by unanimous rising vote, extend to his wife and family its heartfelt sympathies and desires to express its recognition of the service of Mr. Cooley in the development of better roads in the United States, in which movement Mr. Cooley was one of the pioneers and a consistent supporter. The members of the association realize that Mr. Cooley's life aud work have been extremely successful, still they can not help but grieve for the loss of his kindly sympathetic personality which has been an inspiration to many of the members of the association.

ON THE DEATH OF ED SCOTT.

Whereas the cause of highway development has lost an able and devoted servant, and this association a valuable member, through the death of Ed Scott, member of the State Road Department of Florida: Therefore be it

Resolved, That this association extend to the family of Mr. Scott and to the State of Florida its deepest sympathy on account of their irreparable loss. Be it further.

Resolved, That the secretary of this association be instructed to forward a copy of this resolution to the family of Mr. Scott and to the State Road Department of Florida.

ASSOCIATION OFFICERS FOR 1920.

The following officers were elected by the American Association of State Highway Officials at the Washington meeting:

President, W. S. Keller, State highway engineer, Alabama.

Vice president, S. E. Bradt, superintendent of highways, Illinois.

Secretary, J. H. Mullen, chief engineer, Minnesota.

Treasurer, L. A. Gillette, State highway engineer, New Mexico.

Executive committee:

Austin B. Fletcher, State highway engineer, California, 1925.

W. R. Neel, State highway engineer, Georgia, 1925.

Rollen J. Windrow, State highway engineer, Texas, 1923.

Paul D. Sargent, chief engineer, Maine, 1922.

Members of the executive committee whose terms hold over are: George P. Coleman, chairman, State highway commissioner, Virginia, 1922; Thomas H. MacDonald, chief, Bureau of Public Roads, 1924; George E. Johnson, State engineer, Nebraska, 1924; Ira R. Browning, State road engineer, Utah, 1923; W. D. Uhler, chief engineer, Pennsylvania, 1921; C. J. Bennett, State highway commissioner, Connecticut, 1921.

The Address of the Secretary of Agriculture.

E. T. MEREDITH, Secretary of Agriculture.

I AM genuinely glad to have the privilege of welcoming to Washington the American Association of State Highway Officials, an organization composed of men upon whose shoulders rests the responsibility for providing the Nation with highway facilities equal to its needs. I do not think it is an exaggeration to say that no single thing will contribute more largely to the development of our national life and the upbuilding of our country as a whole than the great highway system upon the construction of which the institutions we represent are now engaged.

The national road-building program, authorized by the Federal aid road act of July 11, 1916, has clearly demonstrated that the Federal and State Governments can cooperate closely and successfully in large undertakings. And yet I have heard it frequently stated that such large national problems can not be successfully dealt with under our dual system of government. One group says that there is a tendency for the National Government to encroach upon the field of the States, while another thinks that the Federal Government in order to make its work effective should extend its authority to the smallest political unit. Both groups, apparently, find no difficulty in agreeing that the States and the National Government are working at cross-purposes. Let us not be disturbed by these voices. Similar expressions have been heard since the first days of the Continental Congress, and 145 years of successful operation has not silenced them. But all of us here, I am sure, have faith in our Government, in the stability of its dual character, and in the ability and willingness of the Federal authorities and the authorities of the 48 States to work harmoniously and successfully under it. We all realize, I know, that satisfactory cooperation requires a genuine feeling of mutual confidence and good will and an earnest desire and willingness to be helpful to each other. This is clearly indicated by the manner in which our respective organizations have worked together in the common task of building good roads for the Nation.

PROMPT ACTION IMPERATIVE.

The matter of largest immediate concern to us is the making of adequate provision for the continuation of the road-building plan embodied in the Federal-aid road act of 1916 beyond the period covered by the existing appropriations. Prompt action in this matter is imperative for a number of reasons. The complete success of the work as a whole depends in no small measure upon the certainty with which we and those who work with us can plan ahead for a number of years. Forty of the State legislatures will be in session this winter, when it will be necessary for them to make the requisite provision for meeting future Federal apportionments. Furthermore, we are now threatened with a situation which we feared would exist when our soldiers were returning from overseas. Unemployment is already in evidence in some sections of the country and may become more general. A continuation of this great program of public improvement will help to take up the slack in employment. The Federal-aid road work should be so provided for that it can go forward upon short notice in any district and at any time. It is impossible, however, to develop great construction operations quickly. Months must intervene between the making of appropriations and the paying out of money for labor. I am told that ordinarily a year and a half will elapse between the time when funds are made available for road operations and the time when they can be paid out in considerable amounts. We should know, therefore, without delay whether the necessary appropriations will be provided for the continuation of the existing program during the next five years.

ROAD BUILDING A MEASURE OF PROGRESS.

Immediate action is desirable also in order that our national vision of highway building as one of the greatest public undertakings during the next quarter of a century may not be obscured. This vision has come only after years of debate and opposition, and it has required a national catastrophe to awaken the public as a whole to the inadequacy of our transportation facilities and to the fact that we must depend largely upon our highways, in conjunction with motor vehicles, when a sudden expansion in transportation is necessary. Our experiences during the past three years clearly indicate that the failure earlier to inaugurate a sound highway improvement program has retarded the development of one of our most vital national requirements. The need of better transportation facilities, particularly in rural communities, is too well known to require discussion. Indeed, the degree of transportation development has become a measure of progress in any community, and the part played by it in the betterment of social conditions is generally understood. Certainly it is one of the most important factors in the improvement of rural life.

In my annual report for 1920 I have discussed the progress that has been made in highway construction under the Federal-aid road act, and I have pointed out the steps that have been taken to provide for the full correlation of the work of the department and the State highway agencies through the advisory board of highway officials. I have emphasized the fundamental importance of classifying our highways into groups or

systems of like importance, a problem which the board now has under active consideration. Only through a carefully prepared building plan can the work of the several highway agencies from year to year be placed on a systematic basis, a basis that will provide systems of highways so developed and connected that all classes of traffic will be adequately served. We can not ignore the fact that the actual construction of highways will be limited by physical factors for some years to come; and it seems clear that the only sound policy to follow in the circumstances is that of building roads in the order of their economic importance. Highways, as a general rule, are local institutions, and they must first of all carry the traffic originating in the immediate vicinity. Their normal function, therefore, is the short haul, connecting producing areas with rail shipping points and near-by markets. But we should classify our highways and then follow the classification persistently, to the end that as the principal roads in each State are completed they will connect with those of contiguous States, and thus automatically become links in a national system which will serve all parts of the country. In working out such a classification due consideration must be given to the military needs, and, as you know, provision has been made for cooperation with the War Department in making an extensive study to determine the roads which are required to meet these needs.

E. T. MEREDITH, SECRETARY OF AGRICULTURE.

SOUNDNESS OF PLAN DEMONSTRATED.

The rapid improvement in the organization of the Federal and State highway departments, the development of adequate road legislation in the various States, the response of the States in making funds available to meet the Federal apportionments, and the progress of construction work during a period beset with every possible discouraging condition and limitation have completely demonstrated the soundness of the existing Federal-aid plan. Future legislation should not disturb the principles embodied in the act of 1916, which have been tried out and found to be so satisfactory, and only those changes should be made which experience has clearly shown to be desirable.

As the period covered by the original act as amended will terminate with the close of the present fiscal year, and in order that there may be no halting in the work, I have urged in my annual report that the Congress, at its next session, provide additional funds, to be expended under the terms of existing legislation with certain modifications at the rate of $100,000,000 a year for a period of five years, beginning with July 1, 1921. The principal modifications relate to the problem confronting the Western States in highway work because of the existence in many of them of large areas of public land, and to the maintenance of Federal-aid roads by the State highway agencies rather than by the counties. Your association at its meeting in December, 1919, unanimously approved the continuance of the present plan of Federal participation in road building with these and other modifications.

PROVISION FOR FOREST ROADS.

I have urged also that provision be made for the continued building, on an adequate scale, of roads within or adjacent to the national forests. The forest-road systems are very closely related to those of the States, and the major projects form important links in essential State and interstate highways. There are approximately 15,000 miles of roads within the forests which connect with State and county highway systems. The building of forest roads, therefore, is an important part of the general road development plan of the West. In addition, the transportation of forest products, the protection and administration of the forests themselves, and their utilization for recreational purposes are all dependent upon the construction and maintenance of serviceable roads.

We are gathered here as a family. The institutions we represent are dedicated to public service and we are seeking in our activities to attain a common object. Certainly, therefore, we may discuss our affairs with the candor that should characterize the interchange among members of the same household. We are in general agreement regarding the future highway building policy and program. We know what is required in the way of money and legislative authority for the successful carrying out of the great undertaking devolving upon us. We ought to be equally certain of what we shall require of ourselves.

RESEARCH IMPORTANT IN ROAD BUILDING.

Perhaps the most important contribution we ourselves can make is in the improvement of methods for the construction and maintenance of the roads that will be built within the next quarter of a century, so that they will serve the needs of the country to the best advantage for the longest possible time. I do not need to remind you gentlemen of the basic importance of research as applied to road building. So much has already been accomplished through research effort that we may be inclined to think that not much more work of this character is needed, and that the requirements of the day relate merely to the application of knowledge already available. We can not afford to fall into that error. Research is more essential now than ever before. We are confronted, in the great undertaking before us, with serious problems of the most pressing nature, about which we know comparatively little. I do not mean to imply that we are neglecting the research problems involved in this task. As a matter of fact, the department, in cooperation with the National Research Council and your organization, has instituted deep and far-reaching investigations which, when completed, will solve many of the problems involved in the construction and maintenance of good roadways under a heavy and constantly increasing traffic. I do wish to emphasize the fact, however, that the highway agencies, State and National, must not lose sight of the fundamental importance of continuous additions to the body of scientific knowledge regarding road building, and that every opportunity must be availed of to promote this character of work if we are to justify the responsibilities reposed in us and insure the wise and systematic expenditure of the large sums provided for highway construction.

I wish for you a most successful meeting, and I am confident that from your deliberations and discussions will come much that will be helpful to all those interested in the problem of better roads.

The President's Address.

Paul D. Sargent, Chief Engineer, State Highway Commission, Maine.

THERE has never been a year since the beginning of systematic road improvement in this country when so much was expected of the road building organizations and when so little, comparatively speaking, has been accomplished. We were all proud a year ago to announce that more than $600,000,000 would be available from Federal and State sources for road construction in 1920. The war had been brought to a successful termination; industries converted to the manufacture of war materials were closing down and had not resumed peace-time production; a large supply of labor seemed to be in sight; State highway departments were bending every energy in preparation for the greatest year's program in their history. Contracts were let in the fall of 1919 and during the first four months of 1920 in order that contractors could have opportunity to get construction work under way at the earliest possible date. By May or early June it was apparent that our hopes were not to be realized. Prices bid for work were extremely high and at each successive opening of bids prices increased. New York, I believe, was the first State to revise its scheme for a large program of construction by announcing in May that no more work would be let until prices became stabilized but that every effort would be made to secure the completion of unfinished contracts of earlier years, and to carry out their projected maintenance program. Shortly thereafter many other States reduced their construction programs to cover only 20 to 25 per cent of the work originally planned for the year.

DELAY IN HIGHWAY WORK.

I have no data on conditions throughout the country but it is my belief that not over 25 per cent of the projected program of highway construction has been carried out.

It was soon learned that there was everywhere a shortage of labor for highway work and that wages were as high as, and in many cases higher than, had ever before been paid. We also learned that it would be difficult to secure construction materials or equipment requiring rail haul. One case may serve to illustrate the difficulties of this kind. I had a contractor who ordered a construction outfit in May with a promise of delivery June 15. The plant was ready for delivery on time, but the railroad would not handle it, and delivery was actually made in September, a part of the haul on each end being made by motor truck.

On account of conditions, and to appease the public demand for highway construction, resort has been had to various methods of carrying on work. Contracts have been let on a cost-plus-percentage basis, on a cost-plus-fixed fee, with and without bonus and penalty, and much work has been undertaken on a straight force-account or day-labor basis. Many departments have entered into construction arrangements which would never have been countenanced under normal conditions. In many cases types of construction have been changed from those originally planned because it was impossible to secure materials to carry out the work as designed. In my own State we have surfaced several roads with gravel from local deposits, where we had planned to build a bituminous macadam. We have also built subgrade, culverts, and foundation work on several jobs and put a surface of 3 or 4 inches of gravel on them, hoping to be able to lay the pavement during 1921. These improvements will give immediate relief where conditions have previously been bad.

There is something to be said in favor of this method of construction even in normal times. Undoubtedly many failures of expensive pavements would be avoided if the subgrade and foundation work could be done and the road, with a temporary surface of gravel, turned over to traffic for one or two seasons before the final pavement is laid. Weak spots which develop only under traffic could be detected and corrected, and we would feel much more confident of ultimate success when the surface is placed. Furthermore, a cushion of gravel will lend strength and stability to any type of surface. The only objection is that the road must be closed to traffic for two seasons.

While we have all been disappointed at our accomplishments in actual road construction, I believe the fact that we have been unable to spend more money will prove to be a blessing in disguise. Delayed construction, in my judgment, will mean better and less expensive construction.

On account of the inability of the railroads to handle traffic offered, there has occurred a very heavy movement of commodities over the highways. If trucks had not been available for this traffic, many lines of business would have been forced to suspend operations entirely, both from want of raw material and from inability to deliver finished products to merchants and consumers. The results of this traffic many of you realize better than I do. In May last I saw a large collection of photographs taken in many States showing failures of all modern types of highways, many of which were constructed in 1919, presumably in accordance with the best practice then existing.

THE STUDY OF SUBGRADE PROBLEMS.

The direct result of these failures has been to bring about an intensive study of subgrade problems and a study of the amount and effect of highway traffic impact on pavements. Many road builders have apparently thought the construction of a road meant only the building to line and grade of a roadbed out of any material at hand, and the laying upon that of a pavement uniform as to its construction features from end to end of the job. More than likely the specifications for the pavement were taken from the advertising matter of some concern promoting the sale of a particular material. I do not mean to say that material interests are not of great assistance in working out problems of construction. Up to the present time most of the research work in pavement materials and machinery for constructing pavements has been carried on by manufacturers. The public does not seem to object to paying for this work if it can do so indirectly—that is to say, by giving the manufacturer an extra percentage of profit which he adds to his overhead and uses for research and investigation work for his own information and profit first and for the benefit of the public secondly. The real difficulty of this system lies in the fact that the public's representative in many cases is not competent to interpret results and consequently to make wise selection of materials or equipment for a particular piece of work.

PAUL D. SARGENT, PRESIDENT AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS.

In my judgment, each State highway department should have a thoroughly equipped laboratory for research and investigation of problems peculiar to the State. If this is not possible, a central laboratory should be maintained by a group of States whose road problems are similar.

I have referred to the intensive study of subgrade problems now in progress. This appeals to me as being one of the most important developments of the year in the field of highway work. We certainly all recognize as a fundamental principle of engineering that any structure will fail unless it has a proper foundation. No doubt we have all thought we were building proper foundations, but the failures just referred to indicate that we have much to learn about this branch of our work. With the customary promptness characteristic of its administration in recent years, the Bureau of Public Roads is attacking this problem in a vigorous way. Furthermore, committees whose personnel represents highway engineers, road users, and closely allied interests are lending their best thought to a thorough investigation of this problem in all its details. It is too much to hope for an immediate solution of all the questions now under investigation, but my belief is that before the beginning of another road-building season we shall have information at hand which will assist us to design more intelligently that part of our road structures. I will venture

the prediction that when investigations now under way are completed we shall come to the conclusion that lack of thorough drainage or neglect to provide suitable foundations where drainage conditions were bad have been the two underlying causes for most of the road failures. It is impossible to do a thorough job of road building without giving most careful study to and intelligent treatment of these two features.

IMPACT INVESTIGATIONS.

The outstanding development of the year is the investigation of the impact delivered to highway surfaces by the rear wheels of loaded motor trucks. This elaborate set of experiments which has been carried on by the Bureau of Public Roads sheds the first real light on the problem of rational design of road surfaces. If I interpret correctly the results so far obtained in this investigation, it seems to appear that highway impact, and consequently its destructive effect on highway surfaces, does not depend on gross weight of load and vehicle so much as on the actual wheel pressure on the road, which depends largely on the unsprung weight on the rear axle.

One of the compelling reasons for holding this meeting in the city of Washington was to afford opportunity for members of this association to become personally familiar with the experiments the bureau is conducting on the preparation of subgrades and on highway impact. Our program includes an inspection of the field experiments and a presentation of them by the men who have developed and carried them along.

The public should be apprised of the fact that its servants, the highway engineers, have undertaken the solution of these problems much more promptly than their brothers in the railroad profession undertook similar work, for it is only within a few years that railroad engineers have made a scientific study and determination of stresses in railroad track and roadbeds, although railroads have been the standard mode of transportation for three-quarters of a century.

TRUCK TRAFFIC AND ROAD FAILURES.

I have already stated that intensive trucking has proved disastrous to many miles of every kind of highway pavement. Road builders have long said that they should not be blamed for failures if they could not know in advance of construction what loads were to be brought upon the completed highway. The situation existing to-day, it seems to me, is analogous to the owning, constructing, and maintaining of a railroad by a company or corporation which will have nothing to say about the type, character, design, or weight of rolling stock and motive power that is to be allowed to operate over the road. We can all see that such a condition would quickly lead to chaos and ruin. Doesn't that fairly represent conditions on our highways? Roads built for the traffic of 5 or 10—yes; even 2 or 4—years ago, and which successfully carried the traffic then, are ruined to-day by the passage of a few heavily loaded trucks; sometimes one truck absolutely destroys a road so that the road is of no further service for that particular vehicle nor for any other. Moreover, the number of accidents on the highways, many of them fatal, in which motor trucks are involved is increasing.

The public is becoming incensed over this condition, and undoubtedly many of the State legislatures which meet this winter will attempt to pass regulatory measures. I fear that much of the legislation will be based on prejudice or personal spite rather than on real information concerning the subject. Truck owners and truck users may be properly blamed for a lot of the prejudice in the public mind against these vehicles. Overloading and overspeeding are the two underlying causes for most of the damage done to the highways and for most of the accidents in which trucks figure. The former puts too great a pressure upon the highway surface, and both overload and excessive speed put a burden upon trucks, and particularly upon brakes, which they were not designed to and can not handle. The driver of an overloaded truck understands this, and many times he will not leave the crown of the road for fear of getting over the edge of the pavement or of losing control of the machine. "Hogging" the road is the immediate cause of much of the popular clamor against trucks. Owners ought to regulate these matters themselves, but they probably won't. State highway departments should demand the passage and strict enforcement of laws or regulations relative to overloading and speed and should insist that all trucks carry mirrors so mounted on the driver's side that he can see what is behind his truck.

UNIFORM VEHICLE LAWS.

I know that weight and dimensions of trucks have been long discussed and that definite recommendations have been made covering these points. These recommendations have been enacted into law in some States. I wish we might have uniform traffic laws and regulations all over the country. One very real difficulty, it seems to me, in realizing this much-to-be-desired condition, is found in the States which for years have been building improved roads and now have a large mileage of roads not sufficiently strong to carry traffic of the extreme weight recommended. It is entirely possible, however, for a State to pass a law, and at the same time provide for exceptions to the law, even though in the nature of things the exceptions must be quite general. I am inclined to think that many of the States, if they adopted the uniform vehicle law, would have to except from its operation many of their principal through lines or else vest in some body the authority to so regulate traffic that during the critical periods in spring and fall only traffic of a certain weight would be allowed on these roads. Many roads which can not stand the strain at those seasons will

carry the maximum recommended load when subgrades are dry or frozen. While this would cause some confusion, it ultimately would lead to uniformity, for as the roads were worn out they would be rebuilt to the new standard.

On the other hand, many will claim that the regulation of traffic is more or less of a local question. I can hardly conceive of the legislators in my State agreeing that traffic between Portland, with a population of 70,000, and Bangor, with a population of 30,000, requires the same type of highway that is needed between New York and Philadelphia, for example; nor will they agree that our principal trunk line, some 445 miles in length, equal to the road mileage from Portsmouth, N. H., through six States to Baltimore, Md., and of which the Portland-Bangor section is a part, needs such a pavement. The business does not demand it.

Eighty-eight per cent of all motor vehicles registered in my State are passenger cars. Of the motor trucks it is a safe guess that 75 per cent are 3½ tons capacity or under, which will bring only 3 per cent of our total registration of motor vehicles over 3½ tons capacity. This figure checks fairly well with statistics given in Facts and Figures of the Automobile Industry, published by the National Automobile Chamber of Commerce, in which, on page 14 of the 1920 edition, it is shown that of all trucks produced in 1919 those of 5 tons capacity made up 2.9 per cent of the total. I should expect this proportion to hold fairly well in the sparsely settled and agricultural States. The argument will be advanced as to whether in these States it is to be expected that 97 per cent of the highway users should bear the added expense of construction to make a system of highways sufficient to accommodate traffic which is represented by only 3 to 5 per cent of the vehicles using the road.

Undoubtedly the tendency, as truck traffic develops, will be to go to larger units on account of their more economical operation. It has occurred to me that a considerable economy of operation over present methods of highway transportation can be secured by the use of trailers, which will not increase unit wheel or axle loads but will materially increase the usefulness or efficiency of any motor. Rail transportation would never have developed to its present state if each unit of load had been carried on an independent self-propelled vehicle. The railroads have taught us a great many things about road building. We may yet learn from them how to move traffic economically.

FEDERAL AID AND ROAD BUILDING.

Again, financial resources in many States will prevent the carrying out of a program of construction suited to sustain the heaviest types of trucks. Resolutions passed by this association in annual session last years calling for an increased percentage of Federal aid to certain States is sufficient evidence of this fact.

I do not need to remind you that the Secretary of Agriculture has promulgated the allotment of the last available appropriation for Federal aid. No other one thing could have been done which would have stimulated road building as this measure has. Every State now has an organized State highway department and many States have made liberal appropriations to match the money of the Federal Government. It is apparent from the size of many State highway bond issues authorized in the last three years that the voters have anticipated future Federal appropriations and have made financial provision so that there will be no cessation in the prosecution of road programs while waiting to secure State funds by the lengthy process of amending State constitutions.

Many States had a well established program of highway improvement prior to the passage of the Federal-aid act. These States and many others will undoubtedly continue these programs if the incentive of Federal aid is taken away. It is probable that many other States might give up the work now well started without the inducement of Federal assistance. Unless Congress shall make further appropriations, the extent and progress of the work will be much restricted.

I doubt if this association has changed its attitude as expressed a year ago in respect to a continuance of Federal aid. If this is a fact, we will undoubtedly have opportunity to personally interview our respective delegations on Capitol Hill and make our desires known. I might say that this feature was considered by the executive committee in selecting Washington as our meeting place.

FUTURE FEDERAL LEGISLATION.

I can not refrain from taking this opportunity to offer, not in an argumentative way but merely as a suggestion, my views as to the future course of Federal legislation with respect to road improvement.

It is said that history repeats itself; and I am wondering if this will be true in the case of Federal activity in road building. The history of this development has been similar in many of the States. I have taken pains to look up the course of improved road work in one State, together with the results obtained, and I can not bring my mind to any other conclusion than that this is a forecast of the successive steps in Federal legislation. The story briefly told is as follows:

Beginning in 1901 there were 7 years of State aid to towns, supervised as to location and kind of work by 16 boards of county commissioners, with 1,490 separate, distinct, and disconnected pieces of improved road, aggregating 362 miles, built at costs varying between $160 and $11,463 per mile, the average cost being $1,550. State aid continued for 5 more years, but directed by a State highway commissioner. During

this 12-year period there was no provision for laying out a connected system of State highways or trunk lines. The total result of the 12 years' work was 944 miles of roads rebuilt in 4,202 separate sections. If these locations were plotted on a map you would see at a glance where the municipal officers and local politicians lived, for practically every one had a piece of State road by his premises. You will agree with me that this was a record for "fixing roads," for that is just what was done. Bad spots from 100 feet to one-quarter of a mile in length were rebuilt. One could always tell when he was on a piece of State-aid road, but about the time he discovered the fact he had passed over the improved road and was once more on the old road. Several million dollars were spent in this way, but there were no good roads—that is to say, no continuous stretches of good road. Finally the legislators of that State decided it was time to have a real road program.

A commission of three men was created. They were instructed to lay out, construct, and maintain a system of State highways and a system of State-aid highways. Ample funds were provided for carrying out all of this work. For seven years the work has been in progress under the new scheme, and that State is now on the way to securing an adequate system of highways. The Federal aid which goes to that State is used solely on the State-highway system.

THE FINAL FORM OF FEDERAL AID.

I have recited this experience because, as already stated, I believe it represents the several steps we shall pass through as a Nation before we have the Federal-aid law in its final form. I believe there are States in which the Federal-aid funds are being used just as State aid was used in the early years in the example above cited—in constructing a series of disconnected stretches of improved road which begin nowhere and end nowhere, but which no doubt at the present time are the pride of some local politician. I believe there are States where mileage is desired rather than a thoroughly built, good road. In our example we had the prototype in the State-aid road at $160 per mile. State-aid roads, in the State to which I referred, many times did not connect between adjoining townships. Is it not also true that Federal-aid roads in adjoining States do not connect at the State lines?

It will not take 12 years, however, to get Federal-aid appropriations expended in a systematic way. With 8,000,000 motor vehicles using the highways, the public will soon see to it that principal arteries or trunk lines of travel are first reconstructed. If this result can not be obtained under the provisions of the law as it is now written, I believe we shall see a change or some amendment which will provide for the construction of the main arteries of travel in each State first.

My own thought is that, following the example of many of the States, we should have a system of Federal highways, supplemented by a system of Federal-aid highways, and that work on both systems should be carried on simultaneously. I well remember the dissension that occurred in this organization when this matter was under discussion two years ago. I should very much dislike to see a repetition of that. I do believe, however, that we who have such intimate association with this question should express our opinions on a matter of such importance to the Nation. Legislation, it seems to me, is an averaging of the views and opinions of those who know something about the subject matter and take interest enough to get their views before the legislators. It seems to me we can discuss this matter fairly without dealing in personalities, and if we can reach a common ground present our views to Congress. If we can not agree, we can at least agree to disagree and let the matter drop. I have always held that some improvement was better than none, and when I could not get towns to make improvement where I thought the public interest demanded it, I have never placed obstructions in the way of allowing them to proceed on the location they preferred.

I believe there has been much more actual highway construction under the Federal-aid law as it stands than would have been possible during the past three years if the work had been concentrated in the hands of a Federal department. If, however, the work expands in accordance with suggestions I have made, it seems to me that the responsibilities of administering the Federal appropriations will demand either the creation of a Cabinet position or a strong commission to look after this work. As I visualize this development, there will be far more responsibility attaching to it than now attaches to the work of any commission of the Government, not excepting the Interstate Commerce Commission.

Is it not remarkable that in an undertaking of the magnitude of the present road-building program of the country not even the suggestion of scandal or wrongdoing by anyone in executive authority has ever been raised. I believe the work can be kept on this same high plane, regardless of its magnitude, if its administration can be kept free from political influence and bias, as has been the case in the Federal bureau and in practically every State highway organization.

I am fully aware of the pressure that is brought to bear on substantially every highway department for the construction of roads not suited, in the judgment of the department, to the traffic which they will be called upon to carry. I believe it should be the aim of every department to build the best possible roads that the public sentiment of their respective States will allow, and if we can build just a little better, in a few years the public will give us credit rather than condemnation for what we have done. We should have our eyes on the future and not on the past. We are identified with a developing activity whose limits no one can foresee.

Federal-Aid Accomplishments.

THOS. H. MacDONALD, Chief Bureau of Public Roads.

TO MANY here has come to-day the great opportunity to contrast the present highway situation with that existing at the time of the annual meeting of this association at Chicago in 1915—just five years ago. At that time the proposed Federal-aid measure was presented by the executive committee and received the final approval of the association. Many of the States were facing a reactionary wave against modern highway improvement, threatening the authority, even the very existence, of the organizations themselves. A few months later the Federal-aid act had become a law, and even while in one State petitions were being circulated calling on the general assembly to refuse cooperation with the Federal Government, the future of road building in this country was definitely established.

Sharply contrasted with the road-improvement program under the charge of officials in that convention is the immense program going forward under the direction of the officials in this convention. Here are gathered more of the men who are responsible for the development of highway policies than will come together again until this body meets after another 12 months. Highway history is in the making. Our progress in the future is dependent upon a correct analysis of the underlying principles developed by our experience so far and an intelligent forward-looking policy based upon this study.

THOS. H. MACDONALD, CHIEF, BUREAU OF PUBLIC ROADS.

PROGRESS UNDER FEDERAL AID.

Although since 1916 the State and Federal highway departments and road-building agencies have been continuously handicapped, disorganized, and rebuilt, still great progress has been made. The year just ending has been filled with many discouragements and restrictions, and yet surprisingly large and excellent results have been produced. Certainly not all the results which have accrued have been the direct product of Federal aid, but it has seemed desirable to extend the topic to include the broad developments of the last five years, of which the Federal-aid measure has been one of the major factors. Further, it has seemed desirable to treat the progress already made as an index of the possible rate at which highway improvements may be carried on in the future rather than to be content with a summary of the more or less lifeless figures which go to make up the totals. This opportunity can not be satisfied with a bare recital of statistical facts.

Any standard of measurement that will actually indicate what has been accomplished under Federal aid, or, more properly, during the period that Federal aid has been effective, is not the standard of dollars made available or expended for highway purposes or the mileage of highways which has been built. Any conception which seeks to measure progress by these factors is wrong. Any State highway department which fails to sense a different problem than these is missing the main reason for its existence.

THE MOTOR VEHICLE AND THE HIGHWAYS.

During the six-year period since 1914 an astonishing development of the motor vehicle has given us potentially the means for a great increase in our transportation facilities, but the availability of the motor vehicle for this purpose is contingent upon serviceable highways, not of any particular type or character of material, but highways over which, with the maximum public and private economy, motor vehicles in sufficient numbers to supply the highway transportation necessities of the Nation may operate. This, in general, means continuous service, but not continuous service under maximum or peak loads. The extent to which such service is being and will be supplied is the true standard of measurement which should be applied to the past results and the future proposed programs. The motor vehicle in combination with the improved highway has added such a powerful influence to our civilization that we do not yet sense its potentialities. The increase in transportation facilities for the local and short haul afforded by this combination is destined to bring great changes in the conduct

of the activities which go to make up the life of the whole Nation, and will have a far-reaching effect upon its development along every line. The results which have been so far accomplished in a relative sense are unimportant. The important thing is, rather, the way which they point toward the realization of great mileages of adequate highways, and by this test the outstanding development of this period is the sum total of modern highway legislation produced.

ADVANCED ROAD LEGISLATION.

Legislation is the only vehicle through which the public can set in motion activities for its own use and advancement, and no great constructive policy can go forward without adequate authority from the public itself. Here the influence of the Federal-aid act has been potent, and in the great amount of new legislation which has been set up as the law governing highway activities is the greatest result which has come largely as a direct consequence of the Federal-aid act. It is conceivable that such legislation would have come in time, but the same amount of advanced legislation would not have resulted within a decade without this measure to stimulate and guide. Not only is the amount large but there is a uniformity, which will mean larger results than had there been no standard, in the principles in which the State legislatures have shown confidence, and with which new legislation has conformed. In this five-year period there have been new laws providing State participation, State revenues, State highway systems, and State supervision. Entirely new highway departments were established in 5 States, and in about 20 others the highway departments were reorganized and greatly strengthened to carry on the program set in motion by the Federal-aid appropriation. Thus in over half of the States new highway departments were added or those existing were greatly strengthened, and in practically all the others some new legislation was enacted increasing the authority and available funds of the departments. Ten States by a State-wide vote have provided either for constitutional amendments or for State bond issues removing prohibitions and enabling these States to engage in highway improvement. By the passage of the Federal-aid act the Federal Government, after a lapse of nearly 80 years, again assumed responsibility for highway construction, provided funds ample to carry on a large highway improvement program, and provided for general supervision through a Federal department that is a constant force for elevating standards of engineering and construction in the work undertaken.

DEVELOPMENT OF ORGANIZATION.

Next in order of importance to the legislation provided for highway improvement is the development of the organizations necessary to carry on the work. The placing of large, new responsibilities upon the State departments and the Bureau of Public Roads has been followed not only by a growth of the central organizations, but by a systematic expansion of the departments extending down to the men responsible in these organizations who are in immediate charge of all road work carried on through the cooperative funds. Activities of both the State and the Federal departments have been decentralized to facilitate procedure and to place the responsibility upon the men in actual supervision of the work so far as our experience had dictated advisable. The construction work proper has attracted many of the companies and individuals formerly engaged in other lines of construction activities, has brought into the highway building field a large number of men who are experienced in handling large work, and has made available a large amount of capital as well as equipment to carry on the work. It is quite true that these new contractors have come into the field at a very difficult time, and the experience of many has been discouraging, yet the past season has proved to many of them that the highway-contracting field can and will be in the future a profitable field in which to be engaged. Many manufacturing companies have extended their lines of equipment and are engaged in the development of new devices which will prove effective in quantity production.

During the past few years much attention has been given to the development of labor-saving devices because of conditions existing. Producers of road materials have established new plants, enlarged existing plants, and prepared themselves to furnish a larger output of material for this purpose. An effort has been made by a very considerable number of these producers to standardize their product and to produce the sizes and quality of material which the highway engineers are demanding. In addition to the contractors' organizations and equipment which have been made available, every State has profited largely from the distribution of surplus war materials and equipment, and there is now available sufficient equipment in each one to carry on road-building operations of a major character.

Summing up this period, the greatest results are undoubtedly shown by the amount of constructive legislation and the development of the engineering, construction, manufacturing, and producing organizations, and the making available of a large amount of State-owned equipment for both construction and maintenance purposes.

FEDERAL AID TO DATE.

All of this progress has been time consuming and has been carried through at a most difficult period, but there has been produced a situation out of which during the next few years will come a larger production of roads than has yet been considered possible. There is not an indication which fails to confirm this view of the future, yet during this same period the actual

operations under the Federal-aid act have been large. From the engineering and administrative standpoint the following table indicates the progress by years of the project statements approved by the Secretary of Agriculture:

Project statements approved by fiscal years.

Fiscal year.	Number.	Federal aid.	Estimated States' share.	Total estimated cost.
1917	23	$846,152	$999,282	$1,845,432
1918	557	15,478,090	25,575,111	41,053,201
1919	736	38,664,397	52,831,101	91,495,798
1920	1,670	109,830,366	142,699,817	252,530,183
To Oct. 31, 1920	501	24,198,610	40,599,480	64,798,090
Total	3,487	189,017,615	262,705,091	451,722,706

Because of the fact that the project agreements are not executed until after the preliminary engineering work has been completed, the projects financed and ready for taking bids, the following statement of project agreements executed is more indicative of the producing ability of the highway organizations.

Project agreements executed by fiscal years.

Fiscal year.	Number.	Federal aid.	Estimated States' share.	Total estimated cost.
1917	6	$224,717	$322,375	$547,092
1918	218	5,658,458	8,581,481	14,239,939
1919	454	18,048,442	23,583,290	41,631,732
1920	1,286	85,906,556	111,665,070	197,571,626
To Oct. 31, 1920	393	23,745,415	33,324,573	57,069,988
Total	2,357	133,583,588	177,476,789	311,060,377

The extent of the development of the State and Federal highway organizations is well shown by contrasting the engineering output as indicated by the project agreements executed between the fiscal years 1917 and 1920. In 1917 six project agreements were executed, in 1920 1,286, more than 200 times as many. Project agreements in 1917 called for a total expenditure of $547,092, of which $224,717 was Federal aid. In 1920 the total estimated cost of projects was nearly $200,000,000, of which $86,000,000 was Federal aid, an increase of nearly 400 times the amount requested in 1917.

THE RECORD OF CONSTRUCTION.

The construction record also is good. Prior to the fiscal year 1920 only 59 projects, comprising 293 miles and involving Federal aid in the amount of $1,284,806, had been completed.

The fiscal year 1920 added to the list of completed projects 233 more, or nearly four times as many as had been completed up to the beginning of the year. These 233 projects involved 1,384 miles and $7,635,547 of Federal aid, so that the record of entirely completed projects at the end of the year was as follows:

Number of projects completed	292
Mileage of completed projects	1,677
Federal aid allotted to complete projects	$8,920,353
Estimated total cost of completed projects	$20,878,484

The above refers only to entirely completed projects. In addition to these there were at the end of the fiscal year (June 30, 1920) 1,835 more projects under construction, involving 14,940 miles, and Federal aid to the amount of $103,925,094, the estimated total cost of these projects being $241,977,217.

As these projects were reported at the end of the year as being 30 per cent complete in the aggregate, it follows that the work done on these uncompleted projects up to the end of the year would call for approximately 30 per cent of the Federal aid allotted to them, or $31,174,732. This, added to the Federal aid expended on completed projects ($8,920,353) gives a total equivalent expenditure of Federal aid up to the end of the fiscal year of $40,095,085. At the end of the fiscal year 1919, the amount allotted for completed work was only $4,658,749, so that the Federal aid allotted to work completed during the year was $35,436,336.

But until the 1st of July, 1920, we had not yet caught our stride in construction work. In the face of the most serious shortage of rail transportation, between June 30 and October 31, 329 additional projects were completed, or 37 more than had been completed in the four years preceding, making the total completed projects on October 31, 621.

The Federal aid and mileage, of course, were correspondingly increased, and in order to show the amount of the increase the several items are listed below for the two dates.

	June 30, 1920.	Oct. 31, 1920.
Number of projects completed	292	621
Mileage of completed projects	1,677	3,191
Federal aid allotted to completed projects	$8,920,353	$20,900,014
Estimated total cost of completed projects	$20,878,484	$46,740,472

Notwithstanding the great increase in these items for completed projects, the corresponding items for the projects under construction on October 31 were not decreased, but largely increased. On that date there were 17,369 miles under construction, to which had been allotted $121,322,198 of Federal aid. These projects were reported as 43 per cent complete in the aggregate, and the equivalent Federal-aid expenditure upon them as $51,844,586. This amount added to the Federal aid expended on completed projects gives a total of $72,744,600 as the equivalent of the Federal aid expended for completed work up to October 31.

Thus the work completed on October 31, 1920, has consumed, practically speaking, the whole amount of Federal aid appropriated up to February 28, 1919.

STATE CONDITIONS VARY WIDELY.

It will be noted that during the previous four-month period construction was completed requiring approximately $32,000,000 from Federal-aid funds, or $8,000,000 per month. The acceleration of the rate of con-

struction will be large when highway building is operating under more favorable circumstances. It is now apparent, however, that conditions will vary widely between the States. As closely as can be approximated at this time, it appears that if freed from influences which have so hindered construction during the past season, particularly the lack of rail transportation, the rate of expenditure will be greatly increased, and by the end of the calendar year 1921, 8 States will have expended the full amount of their Federal-aid apportionments, 20 more States will have expended or placed under contract all of their funds, 5 will have placed their funds under contract by the middle of the following year, 15 will have placed all of their work under contract by the end of the year 1922. The number of States in each of the above classes may vary somewhat, but the figures here given are based on the best evidence obtainable.

This situation should be clearly understood, because between 30 and 40 of the State legislatures which meet biennially will be in session this winter, at which time questions affecting the future road-building programs should be settled. More than one year should be allowed to get the funds in the State treasuries after the legislation is enacted, and the highway organizations should know the amount of available funds for several years in advance to enable them to carry out the preliminary engineering and administrative work necessary for the inauguration of road-building projects.

While we are seriously suffering from a lack of improved roads, and our production of new roads up to the present year since 1916 has been small, it has been fortunate for the future stability of the road-building program that because of the limitations imposed there has been sufficient time to get the necessary engineering work done much more thoroughly than would have been possible had we gone hastily into a heavy construction program. So it would seem that conditions have worked out well in spite of the discouragements. We have come to see the immense task ahead and the organizations which have succeeded in driving through actual construction in spite of the handicaps can not fail to produce road mileage at an accelerated rate.

WEAK PHASES OF STATE LEGISLATION.

But the big work, considering the general situation, is ahead, and as we go into the heavy construction program in all of the States we must face the immense physical task of transforming the funds which are provided into adequately built roads. There are certain phases in which our present legislation is weak. These weak points have already shown up and should be eliminated in future legislation. It has become very apparent that those States which have provided State funds with which to meet the Federal-aid apportionments have less difficulty in exercising proper engineering control of the design and construction than those States in which the funds are largely provided by the counties or districts. In a number of States it has been necessary to remove constitutional limitations before State funds could be appropriated for this purpose. There is no reason why local funds should not be used with State and Federal funds, but these should be made to augment the other funds.

Referring again to the standard of measurement by which results must be gauged—that is, the extent to which transportation is facilitated by highway improvement—the results of our observation as to the deterioration of roads and the intensive studies which have been carried on during the past year have demonstrated as never before the absolute necessity of adequate maintenance. In about 30 States the Federal-aid projects are maintained under the direct supervision of the State highway departments or the highway departments have funds to maintain the projects if the local authorities fail. In about 18 States the maintenance is under supervision of the local authorities. Probably the majority of those represented here will not question that a principal of any future Federal aid provided should be that the States as States should have control of the maintenance of the roads built under the cooperative funds. More than 40 of the States have established a system of main roads. These systems vary from a restricted mileage up to more than 10 per cent of the total mileage within the State. The aggregate mileage of the main systems is approximately 8 per cent of the total mileage of rural roads within the United States. Further classification of many of these systems is necessary in order that the construction of those roads of the greatest importance should be expedited. In order that there may be a systematic improvement of the highways this classification should be carried forward, and the sequence of the improvement of the roads should be justified, within reason, by the relative uses which they serve. Only by properly laying out highway systems can the task of road improvement be completed within any reasonable period to an extent necessary to give the public adequate highway service.

BETTER STANDARDS ARE NEEDED.

There are other important features which the experience already acquired has pointed out. In many States better standards should be adopted for the basic improvements such as widths of graded roadway, alignment, grade crossing elimination, and building of permanent drainage structures. The comprehensive studies of the relation of soils to road design, particularly the studies which have coordinated surface failures with certain types of soils, have proved beyond doubt the great prominence which should be given soil studies in road designing. In general, more ample surface widths should be provided, and greater attention given to the construction of shoulders. All of these are fea-

tures which make for permanency of design and the first cost, while greater, will be more than compensated by lesser expenditures for maintenance and reconstruction as our traffic grows heavier. Sufficient attention is not yet being given to the control of materials. The results which really count are the finished product. The materials used must be more adequately controlled through laboratory and field tests. To accomplish these results it seems highly desirable that there be more intimate contact between the Federal and State forces. Up to the present time the Bureau of Public Roads has not succeeded in carrying out the amount of inspection originally planned because of difficulty in maintaining a sufficient organization. It seems probable that a larger number of engineers will be available during the coming year, and so far as possible the bureau proposes to render greater assistance to the States in carrying on a large construction program

This whole road movement has been conceived with the idea of providing adequate roadways for the movement of the highway traffic of the Nation. We have not reached a stabilized character of traffic, particularly with reference to the limiting weights of the larger vehicles, and we should not plan the higher types of construction without allowing a considerable safety factor. Our scientific knowledge of the duty imposed upon highways has been largely increased during the past year, and in the face of facts secured it is evident that our highways in the vicinity of the larger centers of population must be more amply designed and more carefully constructed. No matter how true this is, we must not lose sight of the big fact that there are large areas where transportation over the highways is of the greatest importance to our producing population and where roads of the less costly type, particularly well-built gravel roads, will amply serve the purposes if properly maintained.

TYPES OF FEDERAL-AID ROADS.

The building of highways is the means to an end, that of carrying most economically the traffic developed in the communities served. This principle is being carried out in the projects which have been agreed upon between the Federal and State highway departments, as evidenced by the mileage of the various types of road improvement for which the plans and specifications had been approved up to June 30, 1920. Grouping these types by classes, we have:

Type.	Mileage.	Per cent of mileage.	Total cost.	Per cent of total cost.
CLASS 1.				
Earth	3,701	21.5	$21,763,989	7.7
Sand-clay	1,721	10.0	9,854,570	3.5
Shell	27	.2	296,801	.1
Gravel	5,583	32.5	47,151,795	16.8
Gravel (surface treated)	355	2.1	4,136,533	1.5
Total	11,387	66.3	83,203,688	29.6
CLASS 2.				
Water-bound macadam	342	2.0	5,258,779	1.9
Water-bound macadam (surface-treated)	97	.6	1,433,499	.5
Bituminous macadam	714	4.1	16,669,782	5.9
Total	1,153	6.7	23,362,060	8.3
CLASS 3.				
Rock asphalt	51	.3	1,978,293	.7
Bituminous concrete	496	2.9	15,064,756	5.3
Concrete	3,308	19.2	120,629,308	42.9
Brick	351	2.0	15,725,494	5.6
Sheet asphalt	48	.3	1,572,472	.6
Total	4,254	24.7	154,970,323	55.1
CLASS 4.				
Undetermined	392	2.3	19,796,607	7.0

It is unimportant whether all engineers would agree to this classification in regard to all the types. The relative percentages would be little changed between the classes. One big important fact stands out, that all types of roads must be used, and if the traffic demands are to be supplied large mileages of the lower cost roads must be built. The time factor alone will permit no other course, but there are the other conditions of funds available, continued public support, and economical handling of the public's business which can not be met otherwise. The other important fact is that the big percentage of the funds, particularly where the population served is relatively dense, is going into the more durable types of construction.

In closing, as conditions have tended more toward the normal, and limitations have been removed upon the activities of both the State and Federal departments, the spirit of cooperation has steadily improved, and it is needless to say that as the organization of the Bureau looks forward to the biggest year for construction of highways in the history of the United States, it is with the most friendly attitude toward the State organizations and with a desire to produce large results which will reflect credit upon both organizations, and with the sincere hope that at the end of another year the efforts made will have produced greater results than has been possible heretofore.

The Traffic Census.

A. N. Johnson, Dean, Engineering College, University of Maryland.

THERE is a general agreement among all conversant with highway conditions as to the immediate necessity for thorough and systematic work in highway research, and there are already under way well-organized efforts toward this end. Even a brief study of the problems of highway research shows that many of them of the most fundamental character require for their solution a comprehensive knowledge as to the traffic which moves over the highways. It is therefore of the utmost importance that traffic census work be undertaken and this information collected as rapidly as possible. It will be the purpose of this paper to present some of the features that should govern a traffic census.

WHAT HAS BEEN DONE.

There have been collected, from all of the State highway departments, reports as to the traffic enumerations that have been taken, and such other details as could be secured. From these reports there has been compiled as an appendix to this paper a complete summary of the information received, and in addition a brief outline of the traffic census as taken in France during the present year, in Belgium during 1908 (for which the reports have just been received), and the traffic census now underway in England. It is thought that it would be useful to have information of this character collected for ready reference.

For the most part, the traffic records made in this country have been of spasmodic character, and with one or two exceptions have not been taken with any very definite purpose in view other than to record some information which might prove interesting to examine.

The first traffic census taken in this country for any extended period was made in Illinois, 1906–7, where the traffic was counted at some seventy-odd stations continously during a two-year period on an average of four times a month. The data collected, however, are chiefly valuable from an historical standpoint.

The only State reporting that systematic traffic records have been made within the past few years is Maryland, where, since 1912, one-day counts each month have been maintained on all of the State highways. In 1912 there were about 50 stations, to which additional stations have been added as new sections of State highways were built, until at present there are 191. These traffic records have been used to a certain extent to study maintenance costs and have been very valuable indeed in this connection.

THE BASIS OF A TRAFFIC CENSUS.

Let us now examine some of the considerations upon which to base a traffic census and, from the requirements to be met, deduce as much of the detail as possible as to the manner of making such a census.

The great disparity between the amounts of traffic that use a road prior to its improvement and subsequently is to be noted everywhere. This fact makes a general traffic census over a system of roads which have not been improved of little value, although there will probably be certain points on all such systems of roads prior to their improvement where a traffic count would be of assistance to determine something both as to character and amount of traffic that such particular sections of road might be expected to carry after improvement.

A general traffic census, such as has been taken in a number of foreign countries, particularly in England, France, and Belgium, can not have the same application here, except in those localities or States where the roads have been generally improved and where, as a consequence, highway traffic has developed and the principal routes of travel have been defined. Also as a result of the general improvement of the highways the amount of traffic to be noted may be expected to give a fairly accurate indication of the total use to which those communities find it at present profitable and convenient to use the highways.

There are few States in which the highways have been thus generally improved where a traffic census should be of value in this sense. In such a list are to be included Massachusetts, New Hampshire, Connecticut, Rhode Island, New York, New Jersey, Delaware, and Maryland. To this list may, perhaps, be added Ohio, Wisconsin, Minnesota, portions of Pennsylvania, and California. Outside these States there are a number of localities centering around large cities where the roads for a considerable distance have been materially improved, in particular about Chicago, Detroit, Kansas City, St. Louis, Portland, and Seattle. The improved roads about these cities, extending for 15 or 20 miles, are generally confined to the neighboring county.

PURPOSE OF A TRAFFIC CENSUS.

From the summary of traffic censuses that have been made in other countries and various States, which is appended to this paper, it will be noted that there is a wide variation as to the details. Before these can be discussed it is necessary to analyze the purpose of a traffic census and then to adopt such a method of taking the census as will give the data necessary to serve the purpose sought. It is evident that more than this entails unnecessary expense, while less makes the expense incurred of little or no value.

Some of the purposes of a traffic census may be outlined as follows:

(*a*) For the economic evaluation of a highway, i. e., to determine its worth as an investment, or how much may be safely invested in highway improvement.
(*b*) To find the seasonal variation in the use of a highway.
(*c*) For the proper design of a highway.
(*d*) For a rational allocation of reconstruction and maintenance funds.
(*e*) To obtain the cost of operating traffic over the highways.
(*f*) To furnish data for the formulation of regulations governing vehicles and the manner of their use of the highways.

Let us examine what will be required to furnish the data necessary for the purposes above outlined. First, to evaluate the economic worth of a highway it is necessary that both the amount and character of traffic using the highways be known, not only on a few sections of road but for a large mileage constituting a system of highways. We should also have some knowledge of the amount of traffic on the auxiliary roads to such a system.

To determine the total amount of traffic it is necessary that we know the total number of vehicles of all kinds. We should also know what proportion of these vehicles are for freight and what for passengers. We should want to know the number of passengers as well as the net tonnage transported during the whole year and at different seasons of the year, together with some indication of the nature of the products, as agricultural products, both raw and manufactured, manufactured goods, products of mines and quarries, etc.

To allocate the maintenance funds the amount of traffic and its character should be known over all sections of the highways. This same information would also be used to determine the maintenance cost per unit of traffic.

To determine the wear due to traffic on different highways of similar construction, it should be possible to compare the relative amount of different kinds of traffic, the proportion of light and heavy vehicles and of horse-drawn and motor vehicles.

For the proper design of a pavement we should know the heaviest loads to be carried and their frequency, to aid in designing the thickness, for which there will be required also much data from other sources. To determine the width of pavement, the maximum amount of traffic to be carried in each direction for a given period during the day, and whether the bulk of the traffic changes direction according to the time of day, would be the governing factors in deciding whether a pavement should be widened to a three-track or four-track way.

The cost of operating traffic over the highways is one of the most significant factors concerned with the economics of highway building and maintenance.

A. N. JOHNSON, DEAN, ENGINEERING COLLEGE, UNIVERSITY OF MARYLAND.

Until the cost of highway transportation and the elements that affect it are known and applied, true economy in the construction and maintenance of roads can not be attained. The fundamental requirement for data for such a purpose is a reliable traffic census. Not that the census in itself will answer our problems, for there are many experimental data necessary, which are to be secured only by patient and exhaustive study. But these data will be of no practical application until we know the traffic over our highways. For this purpose we shall require to know the total numbers of each class of vehicle using the road and the total tonnage.

To formulate regulations to control traffic, general divisions, as horse-drawn and motor-driven traffic, are evidently essential as well as the number of passenger and freight motor vehicles. The relative frequency of heavy and light loads will be useful to determine the necessity of traffic segregation, while the total amount of traffic using a highway will help to develop rationally other limitations that may be necessary to impose upon those using the highway for transportation.

From what has been said as to the purposes that are to be served by a traffic census, we may now turn to a discussion of the elements of a traffic census which will give the required information.

We have to answer three principal questions: First, as to where traffic enumerations shall be made; second, as to how often—that is, their frequency and duration; and third, as to what shall be enumerated.

LOCATION OF TRAFFIC STATIONS.

Traffic-census stations should be established close enough so that the traffic over a given section of road may be determined with reasonable accuracy. They should not be so close to cities or villages as to include merely local traffic that extends but a mile or less beyond the observation point. As important byroads join the main road, other traffic stations should be established. Some idea of the total number that may be necessary may be gained from the work in Maryland, where on the average there is a traffic station every 7 miles on the State highway system. Additional stations would be required if the traffic carried by the more important side roads is to be known. In England it is not thought necessary to have counting stations in the open country closer than every 10 miles, but they are nearer together in the vicinity of cities. Where traffic is not heavy, counts could be made at crossroads, one observer taking traffic on both roads.

FREQUENCY AND DURATION OF TRAFFIC COUNTS.

Already reference has been made to the conditions under which a general census may profitably be made; that is, a census taken over a widely spread system of roads. Unless such a system has been improved so that traffic uses the roads of the system in preference to the other near-by routes, there is little value to be gained from a widely extended count of present traffic throughout the year. If the roads of the system are not generally improved, it is recommended that counts be confined to two weeks during the summer and fall, a week at a time, counting the traffic for seven consecutive days.

Traffic records throughout the year may be made on certain roads of an unimproved system near larger cities, to which may be applied a traffic factor obtained from observed traffic in other localities of similar environment, but where the roads have been generally improved.

With the data thus collected it would be possible to form an estimate of the expected traffic over a proposed system of State roads yet to be improved, that should closely approximate the relative amounts of traffic the different highways would carry, while giving a reasonable estimate as to actual amounts of traffic that may shortly be expected to develop. Such studies would furnish a sound basis for the determination of the routes and sections of routes most needed for immediate improvement.

Where a traffic census is to be taken over an entire State system of roads, the enumerations should be taken with sufficient frequency to establish the seasonal, weekly and hourly variations. For these purposes it is recommended that the counts should be made on an average of four times a month, each count falling on a different day of the week, the intervals between the counts being as nearly equal as it is practicable to make them. The observations should be made from 12 to 14 hours continuously, the longer time during the summer months.

Night traffic for the majority of the roads which are not near the large centers of population, can be sufficiently well averaged by taking a few typical counts, which need not exceed four or five a year, taken at different seasons of the year. But in the vicinity of all large cities, particularly on those roads where the public makes considerable use of them for riding during summer evenings, the counts should continue far enough into the night to insure that the bulk of this traffic will be included in the summary.

After one or two years' data have been accumulated, the frequency of the counts may be reduced; from one-third to one-half the number will doubtless be found sufficient.

WHAT SHALL BE ENUMERATED.

It is desirable that the classification of traffic be made according to two distinct methods; (1) according to type of vehicle, and (2) according to the destination of traffic, i. e., whether its direction is toward or away from a given center, whether it is farm-to-town or town-to-town traffic, intertown, or traffic through the State. These distinctions as to destination of traffic can usually be discerned by the observer from his general knowledge of the locality and the character of the vehicle and its load, the bulk of through traffic being indicated closely enough by noting those vehicles bearing license numbers of other States or that manifestly carry tourists.

The tally sheets should therefore be divided into two parts, one according to types of vehicles and the other according to destination of traffic, the observer making two marks, one under each of the general divisions, as each vehicle passes, which will be in itself, to some extent, a check upon his work.

The classification of vehicles should be such that the tonnage, both gross and net, as well as the number of passengers can be estimated for any given unit of time. This will require that the tally sheets shall show the traffic for each hour or two-hour period throughout the day, the hourly period being the one recommended. In addition to the total tonnage, the frequency and number of the heavier units should also be shown, for it is these heavier units which determine the critical loads that the road is to carry, and the frequency known will make possible some determination as to how much relative value this portion of the traffic has, and therefore to what extent the engineer is justified in increasing the strength of the road for these heavier units over that required for the average loads which use the road.

To determine the number of passengers and the tonnage it is not necessary for the enumerator to make very nice distinction; probably two classes of passenger vehicles would be sufficient, or not more than three, to

include passenger busses. A few days' count, showing the actual number of passengers and the number for each classification of vehicles, would give a factor by which the enumeration, made as already suggested, could be reduced so as to give with reasonable accuracy the total number of passengers carried over the road for a given period. To estimate the gross tonnage or net tonnage the enumerator need not keep more than three classifications, one for motor trucks of 5-ton capacity and over; one for trucks of 2 to 5 ton capacity; and one for trucks under 2 tons.

A few days' records noting carefully the type and weight of all motor vehicles according to the classification now used in Maryland, for example (see Appendix), will give reliable factors for reduction to secure the gross tonnage. Likewise records in detail of the net loads carried should be made for a few days on some much-traveled road, until several thousand vehicles have been recorded, from which the net tonnage factors may readily be deduced.

These net tonnage factors would vary somewhat for different localities and possibly for the same locality at different seasons of the year, but need not cause any change in the classification to be used on the tally sheets for the general enumerations. They do, however, bring out the necessity for an experienced observer to study the conditions of traffic in different localities in order that the most intelligent and rational application possible may be made in reducing the traffic to a tonnage and passenger basis.

_____ STATE HIGHWAY DEPAPTMENT

TRAFFIC CENSUS

STATION AT _____ _____ DATE

NORTH SOUTH } BOUND TRAFFIC _____ WEATHER

EAST WEST } _____ OBSERVER

HOURS	HORSE DRAWN VEHICLES			MOTOR VEHICLES							
		FREIGHT		PASSENGER				TRUCKS			
	PASSENGER	ONE HORSE	TWO HORSES	MOTOR CYCLES	2 PASSENGER	5-7 PASSENGER	BUSSES	2 TON AND LESS	OVER 2 TO 5 TONS	5 TONS AND OVER	TRAILERS STATE CAPACITY TONS
AM 6-7											
7-8											
8-9											
9-10											
10-11											
11-12											
PM 12-1											
1-2											
2-3											
3-4											
4-5											
5-6											
6-7											
TOTALS											

FARM TO TOWN	INTER-TOWN	THROUGH OR TOURIST	REMARKS

SUGGESTED TALLY SHEET FOR TAKING TRAFFIC CENSUS.

THE TALLY SHEET.

One practical consideration to be kept in mind in the make-up of the tally sheet is the fact that the enumerators will probably be patrolmen or persons of similar limited abilities, so that it is desirable that the tally sheets upon which the actual counts are to be recorded should be made as simple as possible.

The classification recommended to be shown on the tally sheets is as follows:

Horse-drawn vehicles:
- Passenger.
- Freight—
  - One-horse.
  - Two-horse.
  - —— horse.

Motor vehicles:
- Passenger—
  - Motorcycles.
  - Two-passenger.
  - Five or seven passenger.
  - Busses.
- Freight—
  - Two tons or less.
  - Two to five tons.
  - Over five tons.
  - Trailers (giving approximate weight in tons.

The tally sheets are also to show traffic classified as:

Farm-to-town.
Intertown.
Through or tourist.

The tally sheet (see cut) should show the number of vehicles in each direction. For this purpose two tally sheets may be used simultaneously, one for the north or east bound traffic and the other for that bound south or west.

Each sheet is to be divided into hourly spaces 14 hours on a sheet, using additional sheets for night counts.

In addition each tally sheet should show the date of the enumeration, location of the station, weather conditions, the name of the observer, and whether the count was taken on a day of unusual traffic conditions because of some special event happening in the vicinity.

It is evidently desirable that the traffic census taken in one locality should be readily comparable with that

in another, and this will be brought about most effectively if the general purposes of a traffic census are first well understood and developed and the details of making the enumerations made as nearly uniform as practicable. Possibly the suggestions here furnished will help toward such an end.

APPENDIX.

The following summaries of traffic enumerations that have been made in the various States were compiled from information recently furnished the writer by the various State highway departments. Special mention has been made of the classification of traffic that has been used in the different States as well as the duration and frequency of the counts.

For the present purpose it was not thought necessary to give any detailed results of the various enumerations, though in some instances certain general conclusions that had been made have been mentioned.

Acknowledgment is gratefully made to the State engineers who have so generously placed at the writer's command such complete information upon a very short notice.

Alabama.—No traffic counts have been taken by the State highway department except on sections of roads that are to be taken immediately under construction, the census being used as a basis to estimate the annual tonnage to be carried by the road in question.

The report states, however, that Jefferson County, in which is located the city of Birmingham, undertook a traffic census as part of the plan made for a $5,000,000 bond issue. Traffic was observed on practically all of the roads of the county for two days each week for three consecutive months, the observers being stationed at the intersection of two or more roads.

The observers were furnished with blank forms divided into hourly periods. The traffic was classified as follows:

Large trucks.
Small trucks.
Five or seven passenger cars.
Two-passenger cars.
Two-horse wagons.
Single-horse wagons.
Buggies.
Motor cycles or bicycles.
Miscellaneous.

Trucks were noted as being loaded or empty. The average speed was also noted.

The count was made for 14 hours a day. The observers were first stationed approximately 5 miles from the city limits and each week were moved 5 miles farther out on the same road. The census was used to study the classes of traffic using the roads, to estimate the importance of various roads, and to determine the class of surfacing material best adapted for given situations.

The result of the traffic census showed that 80 per cent of the traffic of the county was carried on 20 per cent of the roads, and that 75 per cent of the traffic was motor drawn: also that 75 per cent of the traffic did not pass beyond the 15-mile zone from the center of Birmingham.

Arkansas.—Reported no traffic counts have been made.

California.—No traffic census has been undertaken by the State highway department. During 1920 traffic counts extending over a single day were made by the United States Bureau of Public Roads at stations scattered over the State highway system, but the results of this census are not yet available.

Colorado.—Traffic counts were made in 1917 and 1918 daily during August, from 6 a. m. to 8 p. m., covering many of the State highways. This work was done in cooperation with the county commissioners.

The observation stations were located close to large centers, but outside of the zone of local traffic.

The classification of vehicles on the tally sheets is as follows:

Automobiles:
- Colorado cars.
- Foreign cars.
- Motor trucks.
- Motorcycles.
- Tractors and other engines.

Horse-drawn vehicles:
- One-horse.
- Two-horse.
- Three-horse.
- Four-horse.

A column is included for live stock (horses, cattle, and sheep). The amount of traffic each hour was recorded.

A very instructive description of the results obtained in Colorado was made by Mr. J. E. Maloney, chief engineer of the State highway department, in the Colorado Highway Bulletin for October and December, 1918, and January, 1919. A map of the State highways is shown, with the total tonnage carried by each.

Connecticut.—Traffic counts extending over three days during August for the full 24-hour period were taken at the bridge over the Housatonic River between the towns of Milford and Stratford.

The enumeration was made with the aid of counting machines, the only classification being that between pleasure vehicles and trucks.

Delaware.—Soon after the organization of the State highway department in 1917 a traffic census was taken at 26 points to determine which roads at that time were carrying the greatest amount of traffic. No general traffic census has been taken since then, but counts have been made at certain points to compare with the results obtained by the original census. The traffic counts extended over a period of two months at intervals of eight days from 7 a. m. to 12 midnight.

A comparison of the traffic for 1920 with the records of 1917 shows that in 1920 there is an increase of 72 per cent in the number of vehicles and 34 per cent increase in tonnage, it being noted that the increase in the traffic coincides with the motor registration for the same period.

For purposes of classification the traffic was divided and weighted as follows:

	Tons.
Horse-drawn vehicles:	
1-horse passenger vehicles	0.350
2-horse passenger vehicles	0.500
1-horse freight vehicles	1.000
2-horse freight vehicles	2.500
3-or-more-horse freight	3.500
Automobiles:	
Motor cycles	0.225
Runabouts	1.000
Light touring cars	1.125
Heavy touring cars	2.250
Light motor trucks	2.250
Heavy motor trucks	7.500

The average weights are used to reduce traffic to a tonnage basis.

Florida.—Except in a few isolated cases no traffic counts have been made.

Georgia.—Except in a few isolated cases no traffic counts have been made.

Idaho.—Three traffic counts have been taken during 1920—one in March, one in June, and one in September, respectively. The observation stations were located on the State highways, chiefly at important intersections. No compilation of the results has been published.

The classification divides the vehicles as follows:

One-horse passenger.	Motor cycles.
One-horse freight.	Tractors.
Two-horse passenger.	Bicycles.
Two-horse freight.	Farm machinery.
—— horse passenger.	Saddle horse.
—— horse freight.	Pedestrian.
Roadster.	Loaded freight.
Touring cars.	Number of passengers.
Motor trucks.	

The traffic was also classified as:

Farm-town.	Intercounty.
Interurban.	Interstate.

Traffic counts were taken from 7 a. m. to 9 p. m. for nine consecutive days. It was expected that observers would be obliged to stop vehicles in order to get the information necessary to classify them.

Indiana.—No traffic counts have been undertaken.

Illinois.—During 1906 the State highway department began a traffic census which extended continuously over a period of two years. There were first established 37 traffic stations at different points on the main roads throughout the State, but this number was soon increased to 71. The counts were taken on an average of four days a month, no two successive counts being on the same day of the week. The record of traffic showed the total number of vehicles moving in each direction at a given point hourly from 6 a. m. to 6 p. m. The vehicles were recorded as loaded and unloaded. Horse-drawn traffic was indicated by the observer, showing the number of horses. Motor traffic, of which there was a very small amount, was indicated by the letter "A," thus giving the total number of motor vehicles.

The observations were made by people residing near the roads, usually by women. It is interesting to note that at some of the stations no automobiles were recorded during the entire two-year period.

Traffic counts have also been made during 1910–1912 at many of the stations established in 1906 and 1907. Full details regarding this traffic census are found in the reports of the Illinois highway commission for 1906, page 22, for 1907, page 23, and the report of 1910–1912, page 269.

As the majority of the stations selected are now located upon the new State highway system, much interest will attach to these older records in comparison to those that will be taken on completion of the State highways.

Iowa.—Traffic counts were made at 47 stations on Federal-aid projects in 1917, and 1918 at 87 stations, 40 of which were located on Federal-aid projects, an average of 3 stations per project. The counts were taken for a period of seven consecutive days from 7 a. m. to 9 p. m.

In 1917 the traffic was classified according to motive power, as horse-drawn and motor-driven, and was also classified according to destination, as farm, interurban, tourist, and town traffic. It is noted that 28.6 per cent of the traffic was farm traffic, 46.9 per cent interurban, 6.5 per cent tourist, and 18 per cent town traffic.

Farm traffic includes traffic between farm and town; interurban, from one town to another; tourist, traffic originating outside of the State or within the State and bound for the outside; town, as traffic originating in the town and going into the country and returning to town.

It is noted that the individual enumerators did not classify on the same basis and there resulted considerable variation in the results from the different stations.

The averages for 47 stations show that 86 per cent of the traffic was motor-driven; the average traffic per day, 339 vehicles and 996 passengers. In 1919 the traffic census at 87 stations showed an average daily traffic on the intercounty road system of 300 vehicles per day; motor traffic, 82.6 per cent; horse drawn, 17.4 per cent; farm-to-town, 47.1 per cent; interurban, 46.1 per cent; interstate, 6.7 per cent. These stations were located in 36 counties.

The 40 stations located on Federal-aid projects show a daily average of 260 vehicles; motor-driven, 78.5 per cent, and horse-drawn, 21.5 per cent.

The classification of traffic in 1918 was different from that used in 1917. In 1918 farm-to-town traffic included the two classifications, "farm" and "town," while the interurban classification was divided in 1918 into "interurban" and "intercounty." The 1918 classification "interstate" is the same as the 1917 classification "tourist."

The tally sheets classify vehicles as follows:

One-horse passenger.	Motor trucks.
One-horse freight.	Motor cycles.
Two-horse passenger.	Tractors.
Two-horse freight.	Bicycles.
——horse passenger.	Farm machinery.
——horse freight.	Saddle horse.
Roadsters.	Pedestrian.
Touring cars.	Loaded freight.

The number of passengers was also recorded.

Classification of traffic: Farm-town, interurban, intercounty, interstate.

In 1919 traffic counts were made at 107 stations, the following tabulation being a comparison of traffic for 1917, 1918, and 1919.

	1917	1918	1919
Average daily traffic	339	260	337
Motor-driven, per cent	86.1	78.5	90.3
Horse-drawn, do	13.9	21.5	9.7
Local traffic, do	93.5	78.1	76.6
Through traffic, do	6.5	21.9	23.4

The details of these traffic data are found in the State highway reports for 1917, 1918, and 1919 (1919 not yet published).

Kansas.—Except in one instance in cooperation with county officials, no traffic census has been taken.

Kentucky.—No systematic census has been undertaken. A few traffic counts have been made, but no uniform set of instructions or classifications was used.

Maryland.—A systematic traffic census has been taken at various points on the State roads system since 1912. At that time there were about 50 traffic stations; since then stations have been added as additional sections of the State highways have been completed until in 1920 there were 191 stations covering about 1,600 miles of highways. The counts have been taken once every month for one-day periods, usually from 12 to 14 hours according to the time of the year.

As soon as a new State highway section is opened, traffic counts are secured. The enumerations are taken by the patrolmen, the point of observation being selected so as to represent as nearly as possible the traffic on that particular section of the road.

The classification and weight in tons of vehicles as shown on the tally sheets is as follows:

Vehicles.	Tons.
1-horse:	
Runabouts, open and top-buggies	0.362
Open spring wagons and covered delivery wagons	1.000
2-horse:	
Family carriages and hacks	.562
Delivery wagons, vans, farm wagons, and dump wagons	2.500
Farm wagons, drays, and vans	3.500
4-horse, farm wagons and drays	3.750
6-horse, farm wagons and vans	4.250
1-horse carts	.800
Ox carts	1.000
Motorcycles	.225
2-passenger automobiles:	
Light-weight machines	.900
Medium and heavy weight machines	1.750
5-passenger automobiles, light-weight machines	1.125
5 and 7 passenger automobiles, medium and heavy weight machines	2.250
3 and 4 passenger automobiles, inclosed (like taxicabs)	2.000
Store delivery automobiles, medium and heavy weight, with tops	2.250
½, 1, 1½, and 2 ton hauling trucks	3.200
3, 4, and 5 ton hauling trucks	7.500
Passenger auto busses, light-weight machines	1.150
Passenger auto busses, medium-weight machines	3.000
Passenger auto busses, heavy-weight machines	4.250

The traffic census for a given station for one year is transferred at the central office to cards, the results being reduced to a tonnage basis. These summary cards show the monthly tonnage for each class of vehicle and the total tonnage of all classes for the month.

Maine.—Traffic counts have been taken from 1916 to date. In 1916, 1917, and 1918 there were 18 stations at which the traffic was recorded but at present there are 44 stations located at various points on the State highway system.

The traffic counts are taken for one week, the last week in August or the first week in September, extending each day from 7 a. m. to 7 p. m.

The tally sheets show two-hour periods, and a classification as follows:

Loaded one-horse wagon.	Rubber-tired horse vehicle.
Unloaded one-horse wagon.	Saddle horse.
Loaded two-horse wagon.	Motor cycle.
Unloaded two-horse wagon.	Excessively heavy vehicle.
Loaded four-horse wagon.	Motor runabout.
Unloaded four-horse wagon.	Motor touring car.
One-horse pleasure vehicle.	Loaded motor truck.
Two-horse pleasure vehicle.	Unloaded motor truck.

A distinction was made between vehicles going in opposite directions. The counts were taken by persons with whom the State highway department had an agreement to do the work.

The average percentage of horse-drawn vehicles as noted at six stations in 1916, 1917, and 1918 is shown in the following table. The daily average of the total number of vehicles at seven stations in 1916 varied from 1,207 to 200 and in 1920 from 2,667 to 197, the average being 514 in 1916 and 797 in 1920.

	Horse-drawn vehicles.	Motor vehicles.
	Per cent.	*Per cent.*
1916	15	85
1917	12	88
1918	10	90

Massachusetts.—Four traffic counts have been made in 1909, 1912, 1915, and 1918, respectively. The counts were taken from 7 a. m. to 9 p. m. The observation stations were on the main through roads and so selected as to be away from the influence of merely local village traffic.

In 1909 the census was taken at 238 stations, in 1912 at 156 stations, in 1915 at 192 stations, and in 1918 at 57 stations. The counts were made for seven consecutive days in August and again in October. At a few important points the count was made at night, covering the entire 24 hours.

The classification of vehicles was as follows:

One-horse vehicle, light.
One-horse vehicle, heavy.
Two or more horses, heavy.
Motor truck or bus, small.
Motor truck or bus, 1 ton or more.
Automobile.

A summary of the traffic enumerations made at different times is found in the report of the Massachusetts highway commission of 1918, pages 50–57, also Appendix J.

Based upon average counts at 44 stations on main lines, the increase in motor traffic from 1909 to 1918 was 661 per cent, with a total decrease of horse-drawn vehicles of 62½ per cent and a net total gain of all vehicles of 243 per cent. It is noted that in 1909 there were practically no trucks, in 1912 there were 17, in 1915 the number was 45, and in 1918 there was an average of 75 recorded daily. In 1909 horse-drawn vehicles constituted 57 per cent of all the traffic and in 1918, 6 per cent of the traffic. During the three years 1916–19 it is noted that motor traffic had increased at the rate of 22 per cent a year.

No reduction of the results to a tonage basis is indicated.

Minnesota.—Traffic counts were made between 1912 and 1917 at 10 different points. They were taken during the summer months extending over a period of three to eight consecutive days.

The classifications made were as follows: Automobiles, trucks, wagons, buggies.

The number of State and foreign cars was also noted, together with the number of passengers per car at some of the stations. During 1918–19 traffic counts were extended to some 56 stations, the counts being made during the summer months, usually for a period of six days. The classification was the same as used in the earlier counts, except that practically all stations reported the number of passengers per car.

In 1918 at some of the stations over 30 per cent of the automobiles passing were foreign cars, averaging from 10 to 15 per cent. In 1919 the percentage of foreign cars was slightly decreased, although a number of stations reported in excess of 25 per cent. In 1919 it was noted on one of the heavy-traffic roads that motor vehicles were 80 per cent of the total; in 1919, 99 per cent. From the average of all traffic counts made, it was found that in 1918 motor vehicles were 89 per cent of the total; in 1919, 92 per cent.

The traffic census has been used to gain some idea of the volume of traffic carried by the roads and to make a comparison of the traffic on the various roads.

The report of the State highway commission of 1918 and 1919, issued March 1, 1920, contains a tabular statement of the traffic counts.

Mississippi.—Except in one or two instances to get the approximate number of vehicles on a given piece of road per day, no traffic counts have been made.

Missouri.—Except in a few isolated cases no traffic counts have been made.

Montana.—A few traffic counts have been made. The instructions state that counts are to be taken on four days from 8 a. m. to 4 p. m. and four days from 4 p. m. to 12 midnight.

Three general classifications are made: Automobiles, light and heavy; trucks, light and heavy; wagons, light and heavy.

A column is also provided to note the number of motor cycles and number of head of stock.

Nebraska.—No traffic census has been undertaken by the State highway department.

Nevada.—Three traffic counts covering a period of one week each have been made, during the latter part of October and the first part of November in 1917 and 1920. Two counts were made at two stations in 1917 and at one station in 1920 at the same point on the road south of Reno where counts were taken in 1917.

Enumerations were made from 7 a. m. to 9 p. m., the tally sheets showing the following classifications:

Horse drawn vehicles:
- One-horse, light vehicle.
- One-horse, heavy vehicle.
- Two or more horses, light vehicle.
- Two or more horses, heavy vehicle.

Automobiles:
- Runabout.
- Touring car.
- Motor truck.
- Motor cycle.
- Miscellaneous.

The average daily traffic on the road south of Reno is given as follows:

	Horse-drawn.	Automobiles.	Truck.
1917	70	355	20
1920	42	647	45

New Hampshire.—A traffic census was taken during 1918 at 57 observation stations on trunk-line roads. The counts were made for seven consecutive days during June, July, August, and September.

The classification used was as follows:

Horse-drawn traffic:
- Horse without vehicle.
- One-horse vehicle, light.
- One-horse vehicle, heavy.
- Two-horse vehicle, light.
- Two-horse vehicle, heavy.
- Three-horse vehicle, heavy.
- Four-horse vehicle, heavy.

Motor traffic:
- Motorcycle—
  - New Hampshire.
  - Foreign.
- Two-passenger car—
  - New Hampshire.
  - Foreign.

Motor traffic—Continued.
- Three-passenger car—
  - New Hampshire.
  - Foreign.
- Four-passenger car—
  - New Hampshire.
  - Foreign.
- Five-passenger car—
  - New Hampshire.
  - Foreign.
- Seven-passenger car—
  - New Hampshire.
  - Foreign.
- Freight trucks, omnibusses, etc.

At most of the stations it is to be noted that the foreign cars are considerably in excess of the cars registered locally. On some of the roads the foreign cars were five times as numerous, averaging between two and three times as many.

The results of the census are shown by diagrams in the State highway report of 1917–18.

New York.—Some traffic counts were made on the State highways in 1909, 1914, and 1916. A four-day census from 8 a. m. to 8 p. m. was taken about the 1st of September in these years on practically all of the important highways of the State and instructions were

issued August 2, 1920, for a similar census extending over a 12-hour period on one Saturday and one Sunday during August.

A total increase of traffic from 1916 to 1919 of 115 per cent was recorded.

The traffic of 1919 compared with 1909 shows a twentyfold increase, although the horse-drawn traffic of 1919 was but 36 per cent of that recorded in 1909. The increase in motor traffic from 1916 to 1919 was 148 per cent, while the increase in the number of motor licenses during this same period was 77 per cent. The conclusion drawn is that each car was making a greater road mileage.

The classification used was as follows: Automobiles, New York State, other States; light delivery trucks; all other trucks; one-horse vehicles; two-horse vehicles. No reduction of results to obtain the tonnage is indicated.

Oklahoma.—No traffic counts have been undertaken except one or two days' observation on a particular stretch of road to determine whether the traffic was too heavy to justify a certain type of construction.

The classification of the traffic was made as follows: Heavy and light horse-drawn vehicles; pleasure motor vehicles and trucks. No special forms on which to record the traffic were used.

Ohio.—Except in a few isolated cases no traffic counts have been made.

Oregon.—Except in a few isolated cases no traffic counts have been made by the State highway department. In the few instances where traffic has been counted, the classification made was as follows: Automobiles licensed in the State, licensed outside of the State; trucks, divided according to capacity as nearly as could be judged; and horse-drawn vehicles.

Observation stations were at points about midway between important towns in order to eliminate local traffic. The counts made extended from 8 a. m. to 6 p. m., but the report recommends that they should be made throughout the 24 hours.

Pennsylvania.—The only report at hand is for a traffic count made by the State highway department on the Lincoln Highway, taken for a 14-day period, hourly from 7 a. m. to 7 p. m., during the autumn of 1920.

The classification used was as follows:

One-ton truck.
Two-ton truck.
Three-ton truck.
Four-ton truck.
Five-ton truck.
Touring car.
Motor cycle.
One-horse vehicle.
Two-horse vehicle.

Rhode Island.—Traffic counts were taken by the State highway department in 1907, 1908, 1913, 1915, and 1920. The earlier tally sheets used contained a much larger number of classifications than the forms used at present.

An attempt was made to have the observers record the weight of vehicles, but it was found difficult to arrive at accurate figures by this method. The tabulation shows results of counts during August of different years.

The classification now in use divides vehicles into: Automobiles, motor cycles, motor trucks, heavy wagons, light wagons.

Observations were made at 19 stations on different roads throughout the State, so selected that the results would not be influenced by purely local traffic.

The traffic census has been used as a basis for designing roads and planning expenses. The count is made from 6 a. m. to midnight. The tabulation at hand shows the census was taken on seven consecutive days, from August 1, during 1913, 1915, and 1920, but there is no indication as to the time of previous counts.

It is noted that the increase of all traffic in 1920 over that of previous years varies from 52 to 378 per cent, but at all points remarkably uniform decrease in wagon traffic is recorded, varying from 54 to 89 per cent. The average daily number of trucks has increased enormously, being as high as 1113 per cent on one road and on none is it reported as less than 156 per cent.

South Dakota.—Except in a few isolated cases no traffic counts have been made.

Tennessee.—No general traffic counts have been made but fairly accurate counts of traffic on special road projects are attempted.

Texas.—No traffic counts have been taken by the State highway department. The data that have been collected have been secured through the county engineers, the counts extending from 7 a. m. to 7 p. m.

The classification of vehicles is as follows: One-horse, loaded, unloaded; two-horse, loaded, unloaded; two-or-more-horse, loaded, unloaded; runabout; touring car; motor truck. Also the record provides for information regarding the type of road, weight of load, principle commodities hauled, approximate weight and kind of heaviest loads, and the width of tires of such vehicles.

Utah.—Except in a few isolated cases no traffic counts have been made.

Vermont.—Except in a few isolated cases no traffic counts have been made.

Washington.—The State highway department has requested the county engineers or the maintenance engineer to report the daily volume of traffic on each section of primary highways. Single day's traffic is to be counted during the period of greatest highway travel. Traffic stations are to be located at junctions making a count upon two roads at once. The counts are to extend for one day for the full 24 hours.

The classification of vehicles is as follows:

1. Motor vehicles:
   - (*a*) Motor cycles.
   - (*b*) Touring cars.
   - (*c*) Trucks (up to 2 tons).
   - (*d*) Trucks (over 2 tons); tractors, etc. (over 5 tons).
2. Horse-drawn vehicles:
   - (*a*) Carriages and light wagons.
   - (*b*) Stages and freight wagons.

N. B.—Tonnage stated refers to truck only, regardless of load.

West Virginia.—Except in a few isolated cases no traffic counts have been made.

Wisconsin.—Traffic counts have been taken at 100 stations throughout the State for the past three years (1918, 1919, 1920). The traffic record is divided between Wisconsin cars and foreign cars, trucks, motor cycles, and horse-drawn vehicles.

The counts began at 6 a. m. and continued until 11 p. m., and were made through cooperation with county organizations. The tally sheets show the hourly variations in the traffic. The observation points were selected by the State highway department near cities on the heavier-traveled roads within a county. During 1919 counts were made four times a month on different days of the week; in 1920 counts have been made twice a month.

The purpose of the census was primarily to determine the traffic that various types of roads were carrying and the cost of keeping these roads up to a certain standard.

It is noted that although one man could make the enumerations at certain stations, two men were required at others, and at a few stations four men were necessary.

Wyoming.—Except in a few isolated cases no traffic counts have been made.

FRANCE.

Under date of May 20, 1920, there was issued by the bureau of national roads of the ministry of public works, a circular of instruction regarding a traffic census to be taken on the national roads in 1920 and 1921, the enumeration to begin August 30 and to continue for a year at intervals of 13 days. The observation stations, as laid out on a chart by the chief engineer, are located in general as nearly as possible at the same points where traffic was counted in 1913. It is noted that changes may be necessary on account of new conditions, due to the establishment of factories, railroad stations, or thoroughfares since the last census.

During the summer months, April to September, traffic counts are made from 5 a. m. to 9 p. m., during the remainder of the year from 6 a. m. to 9 p. m. Traffic counts at night are to be taken as fixed by the chief engineer as frequently as he may decide to be necessary to secure a correct average for night traffic. The classification is the same as for previous counts and is generally comprised in three catagories:

1. Vehicles loaded with produce or merchandise (carts, wagons, drays, trucks, farm wagons, etc.).
2. Public conveyances for travelers, full or empty (omnibusses, diligences, mail carts).
3. Private carriages for travelers (barouches, tilbury carts, etc.), and empty wagons of all kinds except those of the second category.

Animals not pulling vehicles are classed in two categories:

1. Beasts not in harness (horses, oxen, mules, asses).
2. Small cattle (calves, sheep, hogs, goats).

Among the beasts not in harness, those mounted by riders or loaded with packs are distinguished from those not mounted or loaded.

There are besides to be separately enumerated:

1. Automobiles for carrying goods (lorries, vans, delivery cars).
2. Autobusses (automobiles doing a public service in carrying passengers).
3. Private automobiles.
4. Motorcycles.
5. Velocipedes or cycles.

No account is taken of the passage of pedestrians.

Vehicles running on rails will be the subject of a special census for which later instructions will be given.

The circular gives very minute instructions as to the pay of the observers who are cantonniers or road men and receive for this service in general one-half of their pay per day, while for night counts they receive pay for a day and a half.

Observers must pay their own expenses for light, heat, and shelter, unless the position of the observation post is remote from settlement and a special watch house has to be built. There are many other interesting details as to rates of pay in the circular which is signed by the minister of public works.

The tally sheets are divided under column headings into small squares, in each of which, according to the character of vehicles, the observer makes a pinhole. All observations are reduced to "collars," according to the following reduction table:

	Collars.
Conveyances loaded with produce or merchandise	1
Public conveyances for passengers, full or empty	1
Private conveyances and empty vehicles of all kinds except those of the second category	$\frac{1}{2}$
Animals not in harness (horses, cattle, mules, asses)	$\frac{1}{2}$
Small cattle (calves, sheep, hogs, goats)	$\frac{1}{10}$
Private automobiles	5
Velocipedes or cycles	0.05
Motor cycles	0.5
Automobiles for merchandise (lorries, vans, delivery motors)	1.2 P[1]
Autobusses (automobiles doing public service in carrying passengers)	2 P[1]

The results are prepared by the engineers to show the total weight of traffic over each road for which the loads are given, and this total divided by the length furnishes the average load for the road or tonnage per kilometer.

The instructions for reducing the observations as made on the tally sheets are minutely detailed. The average tonnage carried by various roads is shown on maps, the width of the line representing the road being proportioned to the tonnage carried; thus, main roads are shown as broad colored line, while the less traveled roads are indicated by much narrower lines.

BELGIUM.

The report on the census of traffic on the State roads in 1908 was made by the administration of bridges and

[1] P is the weight expressed in tons, established throughout the department.

roads of the ministry of public works and published at Brussels in 1920.

The object of the census was to enable the administration of bridges and roads to classify the roads into three classes, as follows:

1. Roads which by reason of their main direction, their width, and the intensity of their traffic seem to have an importance of the highest order.

2. Roads which in the above respects are of much less importance, ranking comparatively with ordinary county roads.

3. Roads intermediate between the preceding in importance.

As no traffic census had been made since 1879, it was evident a new census would have to be made.

The traffic census was also to be used to note the industrial and commercial progress of the Kingdom, and, "Above all, of the coming of the new mode of locomotion; we mean automobile traffic." The information was used as an authentic and official basis for correct apportionment of maintenance and for further improvement of different roads according to their importance.

The report states that the research justified the expense and that in general it was found that traffic had trebled since 1879.

A traffic census was taken in 1879 during a period of a little over six months, from May to November, counts being made at intervals of 10 days.

The 1908 census extended from March 10 to December 18. The traffic was counted on 24 days distributed so as to come on different days of the week and to include each day of the week. Each day's count continued for 24 hours, the observers being the road men or laborers who were under the direction of inspectors of the department. The observer, as each vehicle passed made a note of the mode of propulsion, the number of wheels, and the kind of transport, while the checker marked the number of passengers and the weight of the load. The report states that only the more intelligent cantonniers and laborers were chosen, upon whose initiative dependence could be placed.

It is noted that while maintenance cost per kilometer has risen 42 per cent it was far from being proportionate to the traffic increase, and that the "running down" of the roads and the expense of maintenance are by no means proportionate to the tonnage transported. On the average it was found that the expense of maintenance for every ton transported in 1918 was 0.014 franc per kilometer compared with 0.031 franc in 1879.

A rather significant statement was made to the effect that the census is not considered to give sufficient data to permit the division of the roads into the three classes as described. The following general remark taken directly from the report makes some important suggestions:

It seems to be opportune to call attention to the question of city traffic. Without going into the question of the necessity of a census of the traffic in the cities we will only say that the census of 1908 gives no indication concerning the internal traffic of Brussels, Ghent, Liege, and the majority of the populous centers.

This may be considered an omission, and with a view to a subsequent census the number and location of the stations adopted for 1908 might, if thought necessary, be revised with the object of reaching this urban traffic and treating it like the rural traffic.

It would be well to have the provincial service set forth * * * the time the last improvement of reconstruction of the road represented by the station * * *.

A supplemental note to this report, dated February 1, 1920, is so suggestive of conditions in Belgium that it is thought worth while to reproduce it here in full:

In the first period of the enemy occupation the employees of the administration of bridges and roads found themselves interdicted without any notice from access to the bureau in the Rue de Louvain, these having to serve as quarters for German soldiers.

The first occupants showed no respect for the records of the administration; they piled a great part of the bundles of papers that they found in the desks of the editors in the central court and burned them, and rain completed the destruction.

Among these records were the principal final documents relative to the results of the traffic census on the State roads in 1908.

Still it has been possible for us to reconstruct them, thanks to what has been preserved of Tables B and C, described in the preceding note; the reconstructed final documents are annexed to the said notes in the form of D tables, except for the Province of Namur, for which no document has been recovered. All that is left of the results for the Province of Namur is found set down in Tables I, II, III, and IV, which were prepared in 1914 and the minutes of which have been recovered.

As regards the diagrammatic maps that were discussed in the note, they have disappeared likewise.

The administration does not deem it worth while to make new ones, since they have no immediate present interest. The new conditions of road traffic are indeed very different from those of 1908; as a consequence of the war there has been an enormous extension of traffic with motor vehicles, and the results of 1908, therefore, do not correspond any more to the actual traffic.

A new census would in principle be demanded, but in our opinion it would be better to wait before proceeding to that until the situation in the interior of the country as regards transport has become normal, until the railroads and country roads have been restored to what they were, with the same intensive service as before the war, until the requisitioned horses and vehicles have been replaced, until the roads, particularly in the devastated regions, have been put back into a state of repair comparable to that of 1914, until the bridges that were destroyed have at last been erected again, until industry has regained its old importance—in short, until the whole country has been raised again from its calamities and ruins.

ENGLAND.

A traffic census has been undertaken this past year in England by the roads department of the ministry of transport. The object of this census is to classify the roads for the purpose of allocating Parliamentary grants toward construction and maintenance.

The census is taken by local highway authorities under the general instruction of the director general of roads. The number of observation points is determined according to the character of the road, but in general on rural roads it is considered sufficient if the count is taken once in every 10 miles, the census stations to be on the open roads, not in villages or at junctions or cross roads.

Approval of the location of the traffic stations together with the dates when the census is to be taken is given by the director general of roads. The forms for taking the census indicate a total period of seven days.

The classification of vehicles is made as follows:

	Tons
Ordinary cycles	0.09
Motor cars (including any motor vehicles not otherwise specified)	1.60
Motor cycles	.13
Motor vans (covered)	2.50
Motor omnibusses	6.00
Motor lorries (rubber tires)	5.00
Trailers to motor lorries	5.00
Motor lorries (steel tires)	10.00
Trailers to motor lorries	5.00
Light tractors	5.00
Trailers to light tractors	5.00
Tractor engines	12.00
Trailers to tractor engines	8.00
Light vehicles (one horse)	.40
Light vehicles (two or more horses)	.60
Heavy vehicles (one horse)	1.25
Heavy vehicles (two or more horses)	2.50
Omnibusses (two or more horses)	3.00
Tramcars	
Horse (led or ridden)	.50
Cattle	.50
Sheep or pigs	.10
Handcarts, etc	
Horses drawing vehicles	.50

These traffic enumerations are a part of a report submitted to the director general to permit classification of roads as: First class, to which 50 per cent of the maintenance cost is to be paid; second class, to which 25 per cent is to be paid; and third class, which receive no contribution.

DISCUSSION OF MR. JOHNSON'S PAPER.

A. W. Dean, chief engineer, Massachusetts: Mr. Johnson's paper shows that in this country traffic census is in its embryo stage, and that thus far the results obtained are really of value only locally, and I should say principally of use in cases of argument. For example, in Massachusetts a traffic census has been taken once in three years since 1908. The principal use of that traffic census has been by the commissioners in conference with parties interested in the construction of a particular road. Such a road, though it may be of great benefit to some individual, is frequently shown by the traffic census to be of little value to the traveling public as a whole. On the other hand, though no particular individual might be interested, the traffic census might show a large use of another road, and thus bring that road to the consideration of the authorities who have the power to place the funds where the funds in their opinion should be placed. As I read Mr. Johnson's paper, Maryland appeared to be the only State that really had a systematic method of taking the traffic census and a systematic tabulation converting the observations into tonnage. Such a conversion makes the census useful, not only for the determination of the amount of use of the road but it is also, to a certain extent, a determination of the magnitude of the loading the road has to carry. The truck weights recorded in the census probably influence the determination of the character of the surface and foundation that should be constructed to a greater extent than the other data recorded, and yet the weights of trucks can not be taken into account alone without taking into consideration also the other factors which affect the choice of surface.

The average vehicular weights in use in Maryland appear to be well chosen, but their proper application would appear to be dependent upon skill and intelligence in the observer. Judging by my experience, I should say it would be impossible to find an observer who could accurately segregate into the 21 different classifications provided on the record sheet all vehicles as they pass, sometimes at the rate of 20 or 30 vehicles a minute, and be sure to get his marks in the right columns. In Massachusetts we use about seven different classes, and even with this simple classification we know the observer does not always put down the count in the right column. In one or two instances trucks have been shown on roads where trucks were prohibited and the road patrolled by a traffic officer, who would stop any truck he saw. My idea is that in arranging for the traffic census we should try to simplify the work of the observer as much as possible and not expect him to do as much as this plan calls for. I do not wish to be understood as criticizing Maryland, because I think the more elaborate classification would be an excellent thing if it could be accurately done. However, I believe that the most that can be done with a reasonable degree of accuracy is to divide the traffic into about five classes, such as light horse-drawn, heavy horse-drawn, light motor vehicles, and, if desirable, have perhaps two classes of heavy motor vehicles under which you would place the small grocery delivery trucks in a class separate from the heavier vehicles, such as heavy trucks carrying stone, sand, steel, etc.

NO CENSUS OF ACTUAL LOADING.

In connection with this matter I have not seen any report of a traffic census that has been taken anywhere showing the actual loading. So far as I have been able to observe the weights recorded have always been estimated. Now, the average enumerator can not tell when he sees the truck going by whether it is a 2-ton or a 5-ton truck. Some of the 2-ton trucks look as large as the 5-ton trucks and some actually have as heavy loads as the 5-ton trucks should carry. In Massachusetts this year the commissioner of public works caused a census to be taken of the actual weights of motor vehicles using the principal through routes in the State. A loadometer was used for the purpose of weighing the machines. This loadometer, if you are not familiar with it, is a small implement that can be carried in any automobile. It operates on the same

principle as an automobile jack, and set under the axle of a truck it weighs as it lifts. Generally the weights of the rear and front axle are taken separately. There is a great value in having the two weights separated because, in many instances, the rear end of the truck is heavily overloaded by as much as 250 per cent. Trucks of a nominal capacity of three-fourths ton were found to be carrying as much as 3 tons, and 5-ton trucks carrying 9 tons were very frequent. Therefore I come back to the statement that assumed weights for the loads that are using the highways are useful but they do not indicate, even approximately, the actual weight of traffic. A chauffeur does not know what his load weighs. If the observer stops the truck and asks the chauffeur how much the truck weighs he does not know unless he is carrying by the ton; then he has a slip showing the weight.

It strikes me, therefore, that we shall come much closer to a representative record of the weight of traffic using our highways by abandoning the attempt to obtain an elaborate classification, and resorting instead to a simplified classification, which can be made by a person of average intelligence, and applying to this classification more accurate average weights determined by actual measurement. The measurements could be made with the loadometer by stationing observers at various points from time to time, without giving warning as to where they are going to be at any time.

I do not think, however, that it is possible at this time to determine definitely what type of surface should be used, basing the determination upon any traffic census. Other conditions will enter into that matter, and enter into it to a very large extent. We might determine to what classes of vehicles certain types of surface would be suitable, but we can not so closely relate the type to the traffic, that, for example, a person in Pennsylvania can tell a man in Virginia what type to use, simply from a description of the traffic.

WEIGHING LOADS FOR REAL CENSUS.

A. B. Fletcher, chief engineer, California: We, in California, have not had any traffic census until very recently, except in a few sporadic cases. Under Mr. MacDonald's direction quite an extensive census has been taken this last fall. The figures, I believe, are not yet available. We are proposing quite an extensive campaign all over the State, using the loadometer, and while I am here I hope to get some information about that device. We have attempted to calibrate two of them ourselves with the testing machine, and we have also had the State department of weights and measures to test them, and we have found them in error by as much as 400 pounds, so that at present I am a little in doubt about the wisdom of using them. There is one dream I have had for several years, which is somewhat in line with the plan Mr. Dean described. Carrying his thought a little further, I think it may be possible to devise an automatic weighing and counting device. Mr. Johnson does not agree with me. He thinks the device would be too complicated and too expensive, but I think it should be looked into more carefully, and I believe it possible in that way to obtain a real traffic census, and I see no other real solution.

REORGANIZATION OF NEW JERSEY STATE HIGHWAY DEPARTMENT.

Effective December 1, 1920, the State highway department of New Jersey has been reorganized as follows:

State highway engineer.....T. J. Wasser.

ADMINISTRATION DIVISION.

A. LEE GROVER, chief clerk, in responsible charge, including the following subdivisions.

Auditing and accounting	M. L. Howell.
Departmental personnel and clerical	Chas. Fishberg.
Purchasing	R. W. Wildblood.
Filing	Miss Grace Williamson.

CONSTRUCTION DIVISION.

C. F. BEDWELL, engineer in charge of construction, in responsible charge, including the following subdivisions.

Right-of-way engineer	R. A. Meeker.
Bridge engineer	C. A. Mead.
Supervisor of State labor	C. A. Burn.
Division construction engineers	Roy Mullins. H. D. Robbins. J. A. Williams.

MAINTENANCE, EQUIPMENT, FEDERAL, COUNTY, AND TOWNSHIP PROJECTS DIVISION.

EDWARD E. REED, assistant State highway engineer, in responsible charge, including the following subdivisions.

Maintenance of State highways and bridges	A. W. Muir.
Superintendent of equipment	N. C. Applegate.
Federal, county, and township projects	A. D. Bullock.
Assistant engineer, in charge of special assignments	H. C. Shinn.

TESTING LABORATORY.

R. B. GAGE, in responsible charge.

NEW CENSUS OF ROAD MILEAGE IN NEW MEXICO.

The State highway department of New Mexico has recently completed a census of road mileage in the counties of the State. The census shows that there are 47,677 miles of rural roads in the State at the present time, as compared with 43,091 miles in 1914, a gain of 4,586 miles in six years.

The mileage of road reported by counties is as follows:

Bernalillo	573	Quay	3,383
Chaves	1,921	Rio Arriba	2,328
Colfax	1,619	Roosevelt	2,067
Curry	2,197	Sandoval	1,299
De Baca	1,851	San Juan	1,078
Dona Ana	1,010	San Miguel	1,620
Eddy	1,181	Santa Fe	940
Grant	1,189	Sierra	634
Guadalupe	3,361	Socorro	3,682
Hidalgo	756	Taos	664
Lea	878	Torrance	1,041
Lincoln	1,046	Union	3,978
Luna	894	Valencia	2,434
McKinley	1,827		
Mora	1,732	Total	47,677
Otero	1,394		

UNIVERSITY OF MICHIGAN AWARDS FELLOWSHIPS IN HIGHWAY AND HIGHWAY TRANSPORT ENGINEERING

FIVE fellowships have been awarded to the following highway engineers and highway transport specialists by the board of regents of the University of Michigan. These men are in residence during the winter period from December to March, inclusive, and are candidates for the degree of master of science in highway engineering or highway transport. The titles of their investigations are included in the statements covering their educational and engineering training.

Roy D. Chapin fellow in highway transport: Herschel C. Smith, Oklahoma City, Okla.; A. B., 1913, University of Michigan; B. C. E., 1915, University of Michigan. Mr. Smith has been continuously engaged in highway work since 1915, having occupied the position of deputy chief engineer of the Oklahoma State highway department, and has been practicing as a consulting engineer, specializing in highway work. Investigation: Highway transport economics.

Roy D. Chapin fellow in highway engineering: Richard R. Fauver, Lorain, Ohio; A. B., 1917, Oberlin College; graduate student in highway engineering, University of Michigan, December, 1919, to March, 1920. Since 1917 engaged in highway construction work with the Ohio Engineering Co. Investigation: Economic aggregates for cement concrete pavements and structures.

Detroit Edison fellow in highway engineering: E. R. Olbrich, assistant professor of highway engineering, Oklahoma Agricultural and Mechanical College; C. E., 1915, Pennsylvania State College. From June, 1915, to November, 1920, Prof. Olbrich was engaged in highway engineering work with the bureau of highways of Philadelphia and the Barrett Manufacturing Co., and in railroad work with the Southern Railway Co. Investigation: Dust preventatives and surface preservatives for gravel roads.

Detroit Edison fellow in highway engineering: Chia T. Yeh, B. Sc. in C. E., 1916, Government Institute of Technology, Shanghai, China; M. C. E., June, 1920, Cornell University. In 1917 Mr. Yeh was appointed by the government of Kwangtung Province to make a survey of 30 miles of military road at Waichow. During 1917 he was also connected with the maintenance of way department of the Kwangtung Samshiu Railroad. In 1918 he was sent to the United States by the Chinese Government to study American practice in highway engineering and highway transport in order to make use of this knowledge in connection with the future development of transportation and highways in China. Investigation: Binding value of Michigan gravels.

National Steel Fabric Co. fellowship in highway engineering: Harold Tuttle Corson; B. S. in C. E., June, 1918, University of Michigan; 1918–19, teaching assistant in charge of sanitary experiment station; and 1919–20, graduate student in civil engineering and instructor in surveying, University of Michigan; June, 1920, to September, 1920, instructor in surveying, Camp Davis; September, 1920, to date, engineer in appraisal office, Ann Arbor. Investigation: Design of cement concrete pavements and foundations as structures.

GRADUATE SHORT COURSE.

Each graduate short period course is given in a period of two weeks and consists of 30 lecture hours in afternoon periods, while the mornings are devoted to library research work in the Davis Library of Highway Engineering and Highway Transport, which is the most complete collection of literature on these subjects in existence. In connection with some courses, the fully equipped highway engineering and automotive laboratories are used for research work. Any man over 21 years of age is admitted to these courses while men holding bachelor's degrees may become candidates for the master of science degree. A man may take one course or a group of courses depending on the duration of his leave of absence from the department or company with which he is connected. The schedule of the courses to be given during January, February, and March, 1921, follows:

January 10 to 21, 1921: C. E. 72, Earth, Sand-Clay, Gravel and Broken Stone Roads, Prof. Bateman; C. E. 81, American and English Highway Transport Methods, Prof. Blanchard.

January 24 to February 4, 1921: C. E. 68, Bituminous Surfaces and Bituminous Pavements, Prof. Blanchard. C. E. 74, Bituminous materials, Prof. Bateman. C. E. 80, Interrelationship of Highway, Railway, and Waterway Transport, Prof. Riggs.

February 7 to 18, 1821: M. E. 40, Mechanism, Operation, and Maintenance of Motor Trucks, Tractors, and Trailers, Prof. Lay. C. E. 69, Highway Laboratory Research, Prof. Bateman. C. E. 70, Highway Structures, Prof. Gram. C. E. 79, American and English Highway Traffic Legislation and Regulations, Prof. Blanchard.

February 21 to 25, 1921: Seventh Annual Michigan Conference on Highway Engineering and Highway Transport.

February 28 to March 11, 1921: C. E. 73, Brick, Cement-Concrete, Stone Block and Wood Block Pavements, Prof. Bateman. C. E. 75, Highway Engineering Seminar, Prof. Blanchard. C. E. 82, Highway Transport Management, Costs and Record Systems, Prof. Blanchard.

March 14 to 25, 1921: C. E. 77, Highway Engineering Financing, Administration, and Organizations, Prof. Blanchard; C. E. 83, Highway Transport Seminar, Prof. Blanchard.

In addition to the members of the faculty of the University of Michigan, between 10 and 15 nonresident lecturers, experts in highway transport, will deliver lectures in the several courses.

The men who registered during December include engineers, contractors, and highway transport specialists, varying in age from 24 to 25 years and coming from the States of Washington, Texas, Oklahoma, Mississippi, Wisconsin, Michigan, Ohio, West Virginia, Pennsylvania, New York, New Jersey, and the Provinces of Quebec and Saskatchewan, and two engineers sent by the Chinese Government to specialize in highway transport.

FEDERAL-AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN NOVEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Alabama	91	Coffee	26.200	Sand-clay	Nov. 4	$242,106.70	$121,053.35
	93	Monroe	20.602	Gravel	Nov. 29	155,415.70	77,707.85
Arizona	20	Navajo	0.946	Bituminous	Nov. 16	62,773.20	22,003.53
	35	Conconino	3.000	Earth	Nov. 4	29,491.00	14,745.50
	37	....do	2.000	Gravel	Nov. 20	29,942.00	14,971.00
	38	Chochise	26.400	....do	Nov. 9	157,140.50	78,570.25
	39	Mohave	23.000	Earth	Nov. 27	175,862.90	87,931.45
Arkansas	98	Woodruff	5.450	Gravel	Nov. 20	106,211.05	20,800.00
	99	Howard	8.470	....do	Nov. 29	57,345.64	26,000.00
	110	Chicot	2.000	Concrete	Nov. 20	37,041.98	4,200.00
	122	Sevier	8.200	Gravel	Nov. 29	27,321.25	12,700.00
California	62	Sutter	5.950	Concrete	Nov. 1	189,541.00	94,770.50
	63	Kings	12.400	....do	....do	505,780.00	252,890.00
Connecticut	6	Litchfield	9.440	Bituminous surface	Nov. 13	419,100.00	188,800.00
Florida	26	Columbia	10.606	Macadam	Nov. 5	451,187.11	212,120.00
Georgia	188	Randolph	5.000	Sand-clay	Nov. 1	34,686.74	15,000.00
	199	Quitman	5.000	....do	....do	35,698.42	17,849.21
	196	Early	6.000	Top soil	Nov. 4	35,943.60	17,971.80
	200	Webster	.....	Bridge	Nov. 1	9,622.27	4,811.13
	202	Wilcox	1.130	Gravel	Nov. 4	22,282.37	11,000.00
	204	Lowndes and Echols	5.650	Top soil	Nov. 29	33,301.01	16,650.50
	40	DeKalb, Gwinnett	[1] 6.446	....do	Nov. 24	[1] 169,560.88	[1] 47,500.00
Illinois	18	Sangamon, Macon, Pratt and Champaign.	8.650	Earth	Nov. 4	317,604.10	79,401.02
	19	Stephenson	2.650	....do	....do	95,071.90	23,767.97
	20	Henry and Bureau	20.000	....do	....do	312,028.02	78,007.00
	21	Warren	.920	....do	....do	55,394.20	13,848.55
	22	Kankakee	.320	....do	....do	7,516.34	1,879.08
	23	Effingham, Clay and Wayne	16.680	....do	....do	774,899.97	193,724.99
Kansas	57	Marshall	[1] 30.500	Concrete	Nov. 18	[1] 1,472,927.50	[1] 147,500.00
Kentucky	45	Breathitt	2.800	Earth	Nov. 1	76,780.00	38,390.00
	46	Hancock	22.200	....do	Nov. 5	359,480.00	179,740.00
Louisiana	67	Tendas	4.320	Sand-clay and gravel	Nov. 1	74,806.29	37,403.14
	76	St. Tammany	39.890	....do	....do	453,896.26	226,948.13
	85	Claiborne	35.010	Gravel	Nov. 4	550,629.75	200,000.00
	83	Caldwell	14.900	....do	Nov. 27	195,749.84	88,000.00
Maryland	40	Baltimore	2.500	Asphalt	Nov. 1	101,730.97	50,000.00
	42	Anne Arundel	2.140	Concrete	Nov. 20	84,727.50	42,363.75
Michigan	39	Clinton	7.250	Concrete or bituminous	Nov. 1	323,785.00	145,000.00
Mississippi	67	Alcorn	8.080	Gravel	Nov. 6	165,429.00	80,000.00
	94	De Soto	11.900	....do	Nov. 4	104,508.80	52,254.40
	108	Holmes	5.000	....do	Nov. 1	67,688.79	25,000.00
Missouri	171	Clark	8.810	....do	Nov. 29	81,260.96	40,630.48
	174	Bollinger	22.000	....do	Nov. 13	154,455.40	77,227.70
Montana	108	Musselshell	[2] 5.300	Earth	Nov. 4	[2] 57,549.80	[2] 28,774.90
	124	....do	7.150	....do	Nov. 1	33,339.40	16,669.70
	147	Glacier	.....	Bridge	Nov. 23	23,584.00	11,792.00
	149	Cascade	1.500	Gravel	Nov. 18	27,830.00	13,915.00
Nebraska	158	Holt	19.000	Gravel and earth	Nov. 29	92,950.00	46,475.00
	169	Adams	.....	Bridge	Nov. 20	10,846.00	5,423.00
Nevada	37	Clark	13.310	Earth	Nov. 12	80,589.74	40,294.87
New Mexico	57	Chaves	12.750	....do	Nov. 4	89,100.00	44,550.00
	58	Union	55.700	....do	Nov. 9	119,627.20	59,813.60
	59	....do	54.000	....do	....do	131,841.60	65,920.80
	61	Bernalillo	5.500	Concrete	Nov. 4	162,002.50	81,001.25
	62	Dona Anna	4.300	....do	Nov. 16	118,635.00	59,317.50
	64	Luna	12.100	Crushed stone	Nov. 29	92,035.13	46,017.56
	53	Torrance	36.000	Earth	Nov. 5	92,763.00	6,381.50
New York	72	Nassau	1.370	Concrete	Nov. 16	68,500.00	23,975.00
	86	Greene	3.600	....do	Nov. 5	205,200.00	71,820.00
	87	Westchester	6.500	....do	Nov. 4	370,500.00	129,675.00
	88	Chenango and Cortland	2.300	....do	Nov. 20	92,000.00	46,000.00
	89	....do	7.700	....do	....do	438,900.00	153,615.00
	90	Herkimer	8.500	Macadam	Nov. 24	340,000.00	170,000.00
	92	Oswego	2.400	....do	Nov. 30	120,000.00	42,000.00
	94	Wayne and Seneca	4.200	Concrete	....do	168,000.00	84,000.00
	97	Ontario	.900	....do	....do	51,300.00	17,955.00
	99	Wyoming	6.200	Bitumin or concrete	....do	353,400.00	123,690.00
North Carolina	32	Edgecombe	[1] 3.100	Sand-clay and gravel	Nov. 10	[1] 14,080.70	[1] 7,000.00
	106	Alamance	[1] 18.000	Bituminous macadam	Nov. 3	[1] 230,639.64	[1] 115,319.82
	113	Caswell	[1] 17.600	Top soil	....do	[1] 136,433.00	[1] 68,216.50
Oregon	47	Jackson	14,356	Gravel	Nov. 12	593,521.50	222,570.56
Rhode Island	12	Washington	6.640	Concrete	Nov. 20	287,485.44	87,676.67
South Carolina	38	Oconee	[3] 11.197	Top soil	....do	[3] 143,948.16	[3] 28,125.18
	88	Anderson	6.777	....do	Nov. 23	48,548.50	20,000.00
	102	Dorchester	12.917	Sand-clay	Nov. 30	144,098.32	45,448.62
	103	York	3.824	Top soil	Nov. 4	33,798.52	13,000.00
Tennessee	41	Knox	15.608	Macadam, concrete, or rock asphalt	Nov. 5	524,190.72	262,095.36
Texas	210	Val Verde	4.540	Gravel	Nov. 1	35,000.00	17,500.00
	213	....do	11.590	....do	Nov. 5	85,000.00	42,500.00
	216	Hemphill	.....	Bridge	Nov. 1	9,958.01	4,979.00
	217	Bexer	5.100	Gravel surface treated	Nov. 4	61,198.54	26,502.24
	218	San Augustine	20.900	Gravel	Nov. 12	296,539.79	100,000.00
	220	Morris	2.694	....do	....do	41,476.00	15,000.00
	221	Colorado	4.570	....do	....do	50,001.49	25,000.00
	223	McCullock	1.500	....do	Nov. 30	10,015.50	5,007.75
Utah	71	Grayson	[1] 1.770	....do	Nov. 6	[1] 14,326.95	[1] 7,163.48
Virginia	26	Bearer	9.560	....do	Nov. 12	125,449.50	62,724.75
	84	Campbell	5.000	Macadam	Nov. 24	162,405.10	81,202.55
	86	Pittsylvania	3.945	....do	Nov. 1	93,060.00	46,530.00
West Virginia	106	Jackson	0.738	Concrete	Nov. 27	23,020.00	11,510.0
	107	Morgan	5.000	Earth	....do	44,309.50	22,154.75
	108	Braxton	5.000	Earth and bridge	....do	69,760.00	34,880.00
	109	Doddridge	1.000	Concrete	....do	38,240.00	18,240.00
Wyoming	64	Carbon	[1] 7.424	Crushed rock	Nov. 26	[1] 73,040.00	[1] 36,520.00
	104	Niobrara	.....	Bridge	Nov. 24	41,360.00	20,680.00
	107	Converse	.....	....do	Nov. 12	33,660.00	16,830.00

[1] Canceled.
[2] Revised statements. Amounts given are increases over those in the original statement.
[3] Revised statements. Amounts given are decreases from those in the original statement.

PROJECT AGREEMENTS EXECUTED IN NOVEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Alabama	79	Dallas	3.144	Gravel	Nov. 15	$53,622.85	$26,811.42
	42	Talladega		Earth	...do....	[1] 29,064.53	[1] 14,532.27
Arizona	28	Pinal	7.522	....do..	Nov. 16	188,899.84	90,000.00
	33	Maricopa	7.060	Concrete	...do....	249,998.88	124,999.43
Arkansas	92	Grant	4.760	Gravel	Nov. 10	30,553.82	14,400.00
Colorado	7B	Montrose	4.027	Earth	Nov. 1	49,525.02	24,762.51
	123	Eagle and Garfield	6.941	....do	Nov. 10	99,548.57	49,774.28
Georgia	4	Oconee and Walton		Top soil	Nov. 23	[2] 12,127.95	[2] 6,063.98
	23	Candler		Sand-clay	Nov. 24	[2] 5,413.22	[2] 2,706.61
	40	Gwinnett	[3] 6.520	Concrete	...do....	[3] 179,790.98	[3] 47,500.00
	51	Colquitt	1.360	Asphalt	Nov. 23	47,038.66	23,519.33
	69	Franklin	3.845	Top soil	...do....	17,532.50	8,000.00
	93	Taylor and Upton	2.881	....do	Nov. 20	103,551.69	49,194.62
	95A	Mitchell	9.970	Sand-clay	Nov. 23	145,633.20	68,476.60
	106	Sumter	2.000	Concrete, bituminous macadam	...do....	[1] 88,305.56	[1] 64,500.00
	115	Chattooga		Top soil	Nov. 20	28,700.87	14,350.43
	120	Carroll	8.546	....do	...do....	92,319.81	39,420.53
	128	Barrow	6.842	Sand-clay	Nov. 23	57,683.72	28,841.86
	130	Baldwin-Putnam		....do	Nov. 20	48,653.80	24,326.90
	133	Troup		Bridge	Nov. 24	158,210.25	50,000.00
	138	Warren	8.840	Sand-clay	Nov. 20	75,943.69	25,000.00
	140	Hancock	10.535	....do	Nov. 23	48,660.20	22,000.00
	141	Richmond	12.680	....do	...do....	52,692.01	24,000.00
	142A	Thomas		Bridge	Nov. 20	40,672.87	16,202.50
	145	Montgomery	12.370	Sand-clay	Nov. 23	79,049.79	31,619.91
	151	Floyd	7.300	Top soil	Nov. 24	76,369.72	38,184.86
	155	Elbert	8.105	....do	Nov. 23	50,069.85	25,034.92
	156	Mitchell		Earth	Nov. 20	39,276.90	15,578.45
	160	Houston		Bridge	...do....	41,950.55	20,975.27
	161	Richmond	2.710	Sand-clay	...do....	79,280.26	35,516.00
	166	Dougherty	2.500	Bituminous concrete	...do....	87,471.26	15,900.00
	167	Fulton	2.470	Conerete	...do....	80,868.97	37,500.00
	168	Jefferson	8.660	Sand-clay	Nov. 23	34,672.07	17,000.00
	170	McDuffie	4.554	....do	...do....	21,975.22	9,000.00
	172	Baldwin	.071	Bridge	...do....	42,363.62	12,000.00
	173	Schley	2.348	Sand-clay	Nov. 24	25,122.06	10,000.00
	175	Wilkinson	2.980	....do	Nov. 23	23,578.03	10,000.00
	176	Lincoln	4.877	....do	Nov. 20	31,251.02	12,000.00
Idaho	15	Bannock	8.175	Crushed rock	Nov. 8	112,392.50	56,196.25
	29	Kootenai	11.820	Gravel	Nov. 6	197,990.11	98,995.05
	34	Oneida	6.250	....do	Nov. 16	49,997.62	24,998.60
	35	Caribou	3.876	Earth and gravel	Nov. 8	47,967.56	23,967.90
	36	Franklin	17.415	Gravel	Nov. 16	159,999.70	79,999.85
	38	Butte	15.398	Earth and gravel	Nov. 8	90,000.00	30,000.00
	39	Lewis	4.260	Crushed rock	Nov. 6	75,051.73	20,000.00
Illinois	2L	Iroquois	.999	Concrete	Nov. 19	39,757.07	19,878.53
	2-4	Will, Kankakee, Iroquois, Lake	.473	....do	...do....	[1] 72,670.16	[1] 36,335.08
	7B to T	Marshall, Putnam, La Salle, Grundy Bureau	.065	....do	...do....	[1] 20,712.85	[1] 9,057.89
	12A, B, C, D, E, F.	Egdar Creek	28.863	Concrete and brick	Nov. 15	1,270,045.74	602,749.40
	14-24 to 33, inc.	Fayette, Marion, Washington	10.546	Earth	Nov. 19	399,249.47	99,812.36
Iowa	15	Mills	13.100	....do	Nov. 20	125,931.96	17,455.35
	51A	Guthrie	12.498	....do	...do....	117,820.45	50,000.00
	55A, B	Scott	15.620	....do	...do....	82,911.07	30,000.00
	58	Benton	17.890	Earth and concrete	...do....	505,256.01	190,400.00
	60	Van Buren	10.790	Earth	...do....	82,566.11	27,000.00
	63A, C, D.	Lucas	11.710	....do	...do....	125,799.13	60,000.00
	65B	Boone	10.570	Gravel	...do....	78,589.94	30,000.00
	67	Hamilton	20.730	Earth	...do....	72,113.30	35,200.00
	80	Ida	18.990	....do	...do....	110,848.21	26,500.00
	99	Carroll	8.960	....do	...do....	83,175.34	41,400.00
	105	Franklin	9.840	Gravel	...do....	75,445.37	34,000.00
	110	Lyon	22.810	Earth	...do....	82,976.63	34,900.00
	116	Cherokee	14.030	....do	...do....	60,861.24	21,900.00
Kansas	32A, B	Dickinson	4.543	Brick or concrete	Nov. 15	304,279.49	68,145.00
Maine	6	Aroostook	5.870	Gravel	Nov. 4	93,950.45	46,975.22
	26	Cumberland		Bituminous macadam	...do....	[1] 25,048.67	[1] 12,524.34
	25	Aroostook	6.120	Gravel	...do....	131,898.74	65,949.37
	27	Cumberland	8.640	Bituminous macadam	...do....	247,349.50	123,674.75
	3f	Oxford	4.570	Concrete	...do....	234,716.59	91,400.00
Mississippi	36	Walthall		Clay, gravel	Nov. 6	[1] 45,759.29	[1] 23,756.89
Missouri	20A	Cass	19.024	Earth	Nov. 22	140,775.88	70,387.94
	33	Polk	13.864	Gravel	Nov. 9	90,496.35	45,248.17
	35	Pemiscot	5.930	....do	...do....	104,089.00	52,044.50
	40	New Madrid	19.810	....do	...do....	279,900.12	139,950.00
	45	Hickory	7.400	....do	...do....	46,211.15	23,105.57
	46	....do	4.490	....do	...do....	28,703.08	14,351.54
	52	Cape Girardeau		Conerete	...do....	[1] 5,549.09	[1] 2,774.55
	53	Lawrence		Gravel	...do....	[1] 23,347.69	[1] 11,673.85
	63	Ralls	3.350	....do	...do....	17,207.96	8,603.98
	64A	....do	4.110	....do	...do....	25,223.40	12,611.70
	65A	....do	4.580	....do	...do....	23,566.26	11,783.13
	72	Hickory	8.100	....do	...do....	56,136.39	28,068.19
	49	Buchanan	20.020	Concrete or bituminous concrete	...do....	1,107,276.90	418,107.69
	66A	Ralls	5.380	Gravel	...do....	52,674.03	26,337.01
	95	Howard	1.000	....do	...do....	11,797.45	5,898.72
	122	Pettis	4.760	Bituminous macadam	...do....	62,996.64	31,498.32
	123	Andrew	.517	....do	...do....	11,601.21	5,800.60
	132	Henry	5.950	Gravel	...do....	59,720.04	29,860.02
Montana	3	Vernon		Flint screenings	Nov. 3	[1] 8,613.76	[1] 4,306.88
	7A	Mississippi		Gravel	Nov. 16	[1] 3,001,92	[1] 1,500.96
	13	Buchanan		Asphalt concrete	Nov. 8	[1] 13,166.51	[1] 6,583.25
	23	Pettis		Bituminous macadam	Nov. 10	[1] 3,483.53	[1] 1,741,76
	27	Fergus	10.890	Earth	Nov. 12	70,195.36	35,097.68
	60A	Park	5.500	Gravel	Nov. 10	50,020,76	25,010,38
	62	Toole	27,480	....do	...do....	155,311,73	77,655.86
	84B,D,G, J.	Roosevelt	21.474	....do	...do....	169,415.85	84,707.91
	91	Musselshell	1,369	Bitumin on concrete	...do....	67,102.06	27,380.00
	94	Meagher	14.070	Earth	Nov. 16	96,514.77	48,257.38
	102	Flathead	2.420	Gravel	Nov. 10	21,292.02	10,646.01
	103A,B	Fergus	15.407	Concrete, earth, and gravel	Nov. 10	199,963.08	93,566.85
	107	Carbon	9.080	Gravel	...do....	88,951.98	44,475.99
	108B	Musselshell	6.527	Earth	Nov. 26	57,346.45	28,673.22
	114	Rosebud	10.910	Gravel	Nov. 3	68,502.77	34,251.38
	64	Ralls		....do	Nov. 16	[1] 9,490.80	[1] 2,847.25

[1] Modified agreements. Amounts given are increases over those in the original agreement. [2] Modified agreements. Second revision. Increase. [3] Canceled.

PROJECT AGREEMENTS EXECUTED IN NOVEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Nebraska	2	Richardson, Nemaha, Otoe		Gravel and earth	Nov. 3	[1] $66,643.66	[1] $33,321.83
	4	Cedar, Wayne		Earth	Nov. 5	[2] 15,183.03	[2] 7,591.52
	18	Gage, Lancaster		do	do	[1] 9,391.21	[1] 4,695.61
	14	Holt	19.922	do	do	123,201.85	61,600.92
	23	Burt, Washington		do	Nov. 3	[1] 14,831.06	[1] 7,415.53
	27	Saunders, Dodge		do	do	[2] 56,194.79	[2] 28,095.50
	33	Knox		do	Nov. 5	[2] 9,602.90	[2] 4,801.45
	49B	Burt	4.015	do	Nov. 3	26,174.19	13,087.09
	57A	Dixon	3.928	do	do	30,633.98	15,316.99
	78	Douglas		do	Nov. 5	[2] 7,538.34	[2] 3,769.17
	98A	Lancaster	11.960	do	do	75,802.25	37,901.12
	100	Douglas		do	do	[2] 6,393.70	[2] 3,196.85
	138	Sarpey	8.460	do	do	58,331.46	29,165.73
	151	Lancaster	.596	Brick	do	42,289.97	10,977.34
Nevada	3	Churchill		Sand-clay	Nov. 3	[1] 23,640.94	[1] 11,820.47
	9	Washoe		Concrete	Nov. 15	[2] 33,637.53	[2] 16,818.75
	12	Lyon	2.270	Earth and gravel	Nov. 25	25,609.28	12,804.64
	14	Douglas		Gravel	Nov. 3	[1] 3,445.20	[1] 1,722.60
	22	Eureka	6.280	do	do	108,823.99	54,411.99
	28	Douglas	1.800	Concrete	do	79,753.74	36,000.00
New Jersey	22	Mercer	.928	do	Nov. 5	75,120.04	18,560.00
	24	Cape May	5.180	do	do	245,199.54	103,600.00
New Mexico	18	Eddy	32.411	Local material	Nov. 10	86,898.29	43,449.14
New York	24	Herkimer		Concrete, bituminous macadam	Nov. 16	[2] 15,530.00	[2] 1,375.00
	27	Cattarangus	7.060	Reinforced concrete	Nov. 27	282,400.00	141,200.00
	28	Wyoming	8.080	do	Nov. 6	323,200.00	161,600.00
	30	Cattaraugus	[7] 1.410	Concrete	Nov. 24	[1] 107,561.45	[1] 11,930.72
	52	Dutchess	3.490	Reinforced concrete	Nov. 15	166,100.00	58,135.00
	56	do	4.890	do	Nov. 18	279,200.00	97,720.00
	64	Suffolk	9.070	do	Nov. 16	362,200.00	174,050.00
	68	Otsego	2.820	do	do	147,000.00	51,450.00
North Carolina	12	Wayne		Sand-clay, gravel	Nov. 11	[6] 18,335.95	
	27A	Orange	[7] 9.727	Top soil	Nov. 10	[1] 19,813.66	[1] 14,972.86
	34	Wayne		Bridge	Nov. 11	[1] 10,815.27	[1] 15,399.00
	39	Union		Bituminous macadam and top soil	do		[6] 12,421.25
	49	Lenoir		Concrete	Nov. 10	[1] 7,159.77	[8] 36,356.21
	50	Guilford		Bituminous concrete	Nov. 16	[2] 23,922.14	[2] 11,961.07
	53	Lenoir		Concrete	Nov. 10	[8] 7,950.92	[8] 32,394.56
	60	do		do	do	[8] 25,280.10	[1] 68,750.77
	38B	Caswell	6.680	Top soil	do	50,907.23	25,453.61
	58	Johnston	6.018	do	do	67,927.25	33,963.62
	75	Columbus	7.031	do	do	66,605.38	33,302.69
	98A	Moore	20.534	do	do	162,943.88	81,471.94
	94A	Mitchell		Gravel	Nov. 11	[1] 28,627.06	[1] 14,313.53
	103	Duplin	11.322	Top soil	Nov. 10	85,550.68	42,775.34
	105	Hoke	9.808	do	do	54,571.55	27,285.77
	111	Forsyth		do	Nov. 11	[1] 29,168.65	[1] 14,584.33
	114	Rowan	.438	Bituminous or concrete	do	[8] 23,706.15	[8] 9,066.49
	116	Stanly and Montgomery		Bridge	Nov. 10	199,218.80	99,609.40
	32	Edgecomb	3.100	Sand-clay, gravel	do	[2] 14,088.65	[3] 7,000.00
North Dakota	6	Eddy		Grading, part gravel	Nov. 9	[2] 11,030.34	[2] 5,515.17
	8	do		Grading and gravel	Nov. 12	[2] 36,873.80	[2] 18,436.90
	22	Towner		Grading	Nov. 9	[1] 6,829.41	[1] 3,414.71
	25	Ward	.277	Gravel	do	[2] 3,601.08	[2] 1,800.54
	28B	Ransom	9.108	Earth	do	58,237.00	29,118.50
	33	McIntosh	18.069	do	do	78,376.61	39,188.30
	38	Hettinger		do	do	[1] 4,174.96	[1] 2,087.48
	43	Bottineau		Gravel	do	[1] 8,990.07	[1] 4,495.03
	45	Foster		Earth	do	[1] 16,021.89	[1] 8,010.94
	46	Traill		do	do	[1] 24,087.32	[1] 12,043.66
	48A	Pierce		Earth	Nov. 30	25,319.89	12,659.94
	51	Grand Forks	1.005	Reinforced concrete	Nov. 9	61,198.00	20,100.00
	65	Stark		Gravel	do	8,658.38	4,329.19
	107	Grand Forks	6.020	do	do	38,541.52	19,270.76
	70	Nelson	5.266	Earth	Nov. 30	29,579.23	14,789.61
	58	Sargent	18.950	do	do	103,613.99	51,806.99
Oklahoma	13	Pushmataha		Steel truss bridge	Nov. 22	[1] 4,342.56	[1] 2,171.28
	16	Hughes		Bridge	do	[1] 5,544.15	[1] 2,772.07
Pennsylvania	86	Potter	.953	Reinforced concrete	Nov. 16	54,526.78	19,060.00
	87	do	1.495	do	do	114,175.50	29,900.00
	89	do	4.103	do	do	244,995.82	82,060.00
	90	Greene	2.611	do	do	175,988.83	52,220.00
	93	Butler	4.939	Sheet asphalt	do	356,535.53	98,780.00
	96	Cambria	4.627	Reinforced concrete and brick	do	393,045.77	92,540.00
South Carolina	55	Greenwood	9.868	Concrete and sand-clay	Nov. 27	134,098.87	57,711.59
Utah	34	Utah		Reinforced concrete	Nov. 11	[1] 7,230.03	[1] 3,615.01
Virginia	47B	Hanover	5.076	Top soil	Nov. 1	20,748.92	10,374.46
	47D	Louisa	7.900	do	do	50,203.07	25,101.53
	47AC	Hanover and Louisa	5.345	do	Nov. 5	29,805.16	14,902.58
Wisconsin	22	Polk		Grading and draining	Nov. 13	[1] 8,929.45	[1] 8,351.18
	46	Waushara		Grading and draining, part sand-clay	do	[1] 12,095.10	[1] 6,282.97
	49	Waupaca	[7] 1.960	Gravel, macadam	do	86,379.30	[8] 662.03
	59	Jefferson		do	do	[1] 55,511.62	[1] 19,283.79
	70	Waupaca	5.450	Concrete	do	205,861.86	69,000.00
	86	Lafayette	[7] 2.175	Earth	do	[8] 7,414.07	[8] 1,587.48
	108	Juneau		do	do	[1] 15,159.68	[1] 5,008.65
	114	Oconto	4.580	Gravel	do	45,975.44	15,000.00
	116	Winnebago	6.270	Concrete	do	206,923.10	70,500.00
	117	Shawano	5.020	Gravel	do	68,572.60	22,857.53
	120	Trempealeau	7.190	do	do	135,992.13	47,996.07
	122A	Pierce	7.600	do	Nov. 24	77,301.43	23,650.71
	130	Price	5.500	Earth	Nov. 13	54,544.03	19,272.02
	131	Adams	4.498	Top soil	Nov. 24	45,671.81	15,335.90
	132	Marquette	5.995	Gravel	Nov. 13	51,790.22	18,250.00
	144	Chippewa	3.580	Earth	Nov. 24	41,474.29	20,000.00
	145	Clark	3.700	Disintegrated granite	Nov. 13	33,139.29	12,000.00
	147	do	5.587	Gravel and disintegrated granite	do	49,782.05	18,891.03
	148	Waushara	4.380	Gravel	do	46,383.78	15,691.90
	154	Fond du Lac	3.590	Concrete	do	123,562.65	42,781.33
	163	Kewaunee	2.970	Gravel	do	43,450.07	16,225.04
	167	Lincoln	5.520	do	do	49,804.84	17,302.42
	172	Richland	3.500	Earth	do	49,395.43	18,000.00
	179	Waukesha	5.860	Concrete	do	290,932.38	91,716.19

[1] Modified agreements. Amounts given are increases over those in the original agreement.
[2] Modified agreements. Second revision. Increase.
[3] Canceled.
[4] Modified agreements. Third revision. Decrease.
[5] Modified agreements. Third revision. Increase.
[6] Modified agreements. Second revision. Decrease.
[7] Decrease in milcage.
[8] Modified agreements. First revision. Decrease.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A Summary.
*393. Economic Surveys of County Highway Improvement. 15c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
724. Drainage Methods and Foundations for County Roads.
*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918. 15c.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads
505. Benefits of Improved Roads.
597. The Road Drag.

* Department supply exhausted.

SEPARATE REPRINTS FROM THE YEARBOOK.

B. Y. Sept. 727. Design of Public Roads.
B. Y. Sept. 739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir.*89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
*Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918. 15c.
Public Roads Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the U. S. 1919.
Public Roads Vol. III, No. 29. State Highway mileage 1919.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D-3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D-8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO 33 WASHINGTON, D. C. JANUARY, 1921

A FEDERAL-AID ROAD SURFACED WITH BITUMINOUS CONCRETE, NEAR ALEXANDRIA, LA.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Shall the State Own and Operate Its Own Portland Cement Plant? . . 3
H. E. Hilts.

Difficulties Experienced by the States in the Matter of Rail Transportation . 16
S. E. Bradt.

Difficulties Experienced in the Matter of Rail Transportation—Discussion . 18
M. W. Watson.

What the Highway Departments May Expect in Railroad Service in 1921 . 21
A. G. Gutheim.

The Relative Value of Different Types of Rural Pavements 24
A. R. Hirst.

The Analysis and Preparation of Estimates for Road Construction . . 32
H. J. Kuelling.

The Study and Treatment of the Different Subgrades and Foundations . 36
Chas M. Upham.

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
SUBSCRIPTION PRICE, $1.50 PER YEAR

SHALL THE STATE OWN AND OPERATE ITS OWN PORTLAND CEMENT PLANT?

H. E. HILTS, Principal Assistant Engineer, Pennsylvania.

IN ANALYZING the question whether the State should own and operate its own cement plant the hypothesis should be developed upon the basis of business economics; it is unsound to attempt to analyze it from the viewpoint of political expediency.

Basic industries in this country have grown and expanded because we are a forward-looking people, as free as possible to work out our individual destinies, and subject only to such governmental balance and control as may be necessary to prevent one individual or group of individuals from interfering unduly with the rights of others. Our present industrial system has grown, developed, and prospered by individual initiative, and this individual initiative it is desirable to maintain. We must not lose sight of this broad generalization in the further discussion of the economics of our question.

There are two principal reasons, I believe, for the consideration which is being given to-day to the matter of State operation of Portland cement plants. The first of these is the difficulty which, especially during the past season, has been experienced in securing cement in sufficient amounts and with sufficient regularity for economical use by the consumer. The second is the increase in the cost to the consumer which has occurred during the past few years.

Before jumping to conclusions it would be well to analyze the developments which led up to the extraordinary market conditions of 1920. It may be that the privately owned plants have not been entirely responsible for the conditions complained of. Indeed, one of the first facts encountered in any analysis of the conditions must be that the producing capacity of the cement plants in this country is at this time, and has been for a long period of years, far in excess of the consumption. Figure 1 shows very clearly the production and consumption during many years in the past. By scanning the curve it will be seen that the cement industry has had a very rapid growth, and the price curve (fig. 2) shows that this growth has resulted in intense competition, brought about by the widespread promotion of plants in all parts of the country.

As with all quick industrial growths, the efforts of commercial promoters have resulted in the establishment of many uneconomical cement plants at inferior locations. Moreover, up to within the past 8 or 10 years the promotional work had resulted in placing many of the cement mills in the hands of men who were not trained in either accounting or business methods. Yet, in spite of these facts, a conservative estimate of the rated capacity of the cement mills of the United States, at this time, is 125,000,000 barrels annually, and this capacity has been available for the past several years.

TABLE 1.—*Annual Portland cement manufacturing capacity of the United States, by commercial districts, 1917 and 1918.*

District.	Estimated capacity (barrels).		Per cent of capacity utilized.	
	1917	1918	1917	1918
Lehigh district (eastern Pennsylvania and western New Jersey)	37,016,132	36,904,000	66.0	53.4
New York	8,552,480	8,411,400	63.3	48.7
Ohio and western Pennsylvania	9,379,040	12,983,000	78.3	49.6
Michigan and northeastern Indiana	8,672,400	7,770,000	60.7	52.9
Southern Indiana and Kentucky	4,336,200	4,550,000	58.1	35.4
Illinois and northwestern Indiana	13,859,780	14,060,000	78.8	51.0
Maryland, Virginia, and West Virginia	4,384,380	4,322,200	71.2	52.7
Tennessee, Alabama, and Georgia	4,657,400	4,500,000	78.9	66.5
Iowa, Missouri, and Minnesota	13,764,480	14,040,000	85.5	67.5
Nebraska,[1] Kansas, Oklahoma, and central Texas	12,197,570	10,579,500	63.2	50.8
Rocky Mountain States (Colorado, Utah, Montana, and western Texas)	4,336,200	4,498,000	75.2	50.9
Pacific Coast States (California, Washington, and Oregon)	15,594,260	15,783,100	47.3	35.2
	136,750,322	138,401,200	67.9	51.3

[1] Nebraska had no output in 1918.

MANUFACTURING CAPACITY AMPLE.

True, the actual production of cement has not approached the limit of capacity. In 1919 the ratio of production to manufacturing capacity was only about 54 per cent, and for the first 10 months of 1920 it was about 67 per cent. Prior to 1920 the most cement that had ever been used in this country in any one year was 94,000,000 barrels in 1916.

What were the reasons for this failure to develop the full capacity of the plants? To answer the question specifically, prior to the war the reason was lack of demand; during the war it was governmental restriction; and in the last year or two it has been demoralized transportation facilities and the inability of the plants to obtain fuel, supplies, containers, etc., regularly and in sufficient quantity to permit of economical operation. These were conditions over which the private cement plants had no control. They affected all business in much the same manner. Every State highway department, for example, has felt the lack of transportation facilities, and knows that it was due, largely, to embargoes, special service orders, strikes, and the general postwar era of extravagant inefficiency of labor.

TABLE 2.—*Estimated surplus or deficiency in local supply of Portland cement in cement-producing States, 1917–18, in barrels,*

State or division.	1917			1918		
	Shipments from mills.	Estimated consumption.	Surplus or deficiency.	Shipments from mills.	Estimated consumption.	Surplus or deficiency.
California	5,659,547	4,608,011	+ 1,051,536	4,238,424	3,606,286	+ 632,138
Illinois	4,378,233	7,189,662	− 2,811,429	3,703,471	4,925,736	−1,222,265
Indiana	8,148,678	3,425,053	+ 4,723,625	6,205,326	2,406,617	+3,798,709
Kansas	3,772,884	1,977,798	+ 1,795,086	2,586,834	1,422,877	+1,163,957
Michigan	4,313,771	4,425,533	− 111,762	3,618,088	3,266,393	+ 351,695
Missouri	5,800,988	2,548,152	+ 3,252,836	4,515,695	1,652,454	+2,863,241
New Jersey	2,397,069	3,120,589	− 723,520	[1]	[1]	[1]
New York	5,408,726	8,920,808	− 3,512,082	4,074,159	6,319,045	−2,244,886
Ohio	1,565,334	6,950,672	− 5,385,278	1,289,887	5,010,482	−3,720,595
Oklahoma	1,736,761	1,443,928	+ 292,833	1,218,841	1,118,595	+ 100,246
Pennsylvania	27,703,442	7,787,055	+19,922,387	22,238,689	6,611,108	+15,627,581
Texas	2,358,944	2,034,548	+ 324,396	1,918,919	1,509,318	+ 409,601
Utah	899,599	526,086	+ 373,513	549,593	350,603	+ 198,990
Washington	1,403,191	1,189,880	+ 213,311	1,116,754	1,044,898	+ 71,856
Maryland, Virginia, and West Virginia	3,109,098	4,087,586	− 978,488	[2] 4,362,442	[2] 7,650,679	−[2]3,288,237
Tennessee and Kentucky	2,628,388	1,852,770	+ 775,618	2,254,277	1,576,991	+ 677,286
Alabama and Georgia	1,672,173	1,267,030	+ 405,143	1,349,174	1,557,691	− 208,517
Iowa, Minnesota, and Nebraska [3]	5,731,652	7,764,443	− 2,032,791	4,196,902	5,564,697	−1,367,795
Colorado, Montana, and Oregon	2,008,936	1,978,624	+ 30,312	1,478,033	1,278,730	+ 199,303
	90,703,474	73,098,228	+17,605,246	70,915,508	56,873,200	+14,042,308

[1] Included with Maryland, Virginia, and West Virginia.
[2] Includes also New Jersey in 1918.
[3] Nebraska had no output in 1918.

A short practical discussion of these conditions as viewed by a large cement corporation is given in the testimony of B. F. Affleck, president of the Universal Portland Cement Co., with mills at Pittsburgh, Chicago, and Duluth, before the Calder committee on "Reconstruction and Production." Mr. Affleck said:

"Our difficulties dated back to August 1, 1919, since which time strikes have interfered seriously with our mill operations. As a result, some jobs for which we could have supplied cement and which might have been completed last fall carried over into this year. The year opened with an extraordinarily heavy demand so that by February 1, 1920, our mills were about 2,300 cars behind on shipments, and about March 1 this figure had grown to 3,600 cars. The peak came in the first week in May, when we were about 6,100 cars behind, the oldest order dating from January.

"The direct cause of these delays was the acute car shortage which was continuous over the first half of the year. There were times early in the year when our cement bins were taxed to capacity, making it necessary to adopt unusual means of delivery to make room for continuous operation of our mills. One of these means was the use of restricted railroad cars, privately owned cars furnished by customers and by ourselves, stock cars, open-top cars which involved the use of tarpaulins to protect the contents, and bad-order box cars. Cement, of course, under ideal conditions is shipped in box cars in good order, but this year we have had to take what we could get regardless of expense and inconvenience. Use of restricted and privately owned cars, for instance, to some extent took the distribution of our product out of our own hands. We were offered at our Buffington, Ind., plant, one day by a certain railroad a number of cars restricted to movement to Minneapolis and St. Paul. Aside from the fact that freight rates to the Twin Cities are much higher from our Buffington mill than from our Duluth mill, we did not want, at the time these cars were offered us, to move so much cement at one time into the Twin Cities, prefering rather to distribute it among a number of customers elsewhere whose needs were most urgent. Many times through the season we have received bunches of these restricted cars and have used them only because we did not have enough unrestricted cars to distribute our product equitably and to keep our loading and packing forces occupied and our mills going.

"Another means adopted to keep our product moving was the use of motor trucks, involving, of course, additional expense to ourselves and our customers. From all our plants about two and a quarter million barrels of cement were moved by truck for the nine months ending September 30. The movement from our Chicago plant at Buffington, Ind., was just under 2,000,000 barrels, of which about a quarter of a million barrels moved to team tracks of trunk lines that do not enter our mills, and more than a quarter of a million barrels to a dock where the cement was loaded onto boats for transportation to lake ports. The extreme to which our Chicago plant went in truck deliveries is shown by the fact that as many as 613 trucks were loaded in a single day, the equivalent of about 120 cars. This was at the rate of more than a truck per minute. The cement requirements of Chicago for this year have been more satisfactorily supplied than perhaps any other city in the country by the use of trucks, and at a saving of about 7,500 railroad cars in a time of acute car shortage.

"The crying need in the construction industry is production in its broadest sense, not only of building materials, but of everything necessary to keep industry going—transportation, labor, fuel, credits, confidence and the last perhaps is greatest of all, since the others will follow it. Confidence and production are needed and lack of them simply adds in a greater or less degree to the high cost of living, and forms a part of the "vicious circle" that has been with us through these war and postwar times."

NOT FAIR TO JUDGE INDUSTRY BY RECENT PAST.

Taking these conditions by and large, it would seem that the extraordinary obstacles encountered during the past six years militate against considering these years as fair criteria in passing judgment on the ability of the industry to produce and deliver in sufficient quantities to meet the demands of 1921 and succeeding years. A State-owned plant would probably have fared no better during these strenuous times, and, very likely, would have suffered in the same ratio as the private industry.

It now seems that our economic processes are in course of orderly adjustment, and that the conditions which have hampered us in the past are slowly but surely being righted. It is fair to assume, therefore, that as conditions improve the production of cement will more nearly approach the potential producing capacity of the existing plants; and certainly there is little to be gained by building new plants, whether privately owned or State operated, until the conditions permit the full operation of existing plants. Having in mind the pre-

nounced activity of the manufacturers in their efforts to augment production and distribution on economical lines, and considering, also, that our transportation facilities will gradually right themselves under private operation, it is likely that more desirable conditions will soon materialize. At any rate, it is improbable that the States will again experience the abnormal conditions which held during the summer of 1920, providing the State officials will acquaint the producers with their estimated requirements.

Taking these features into consideration, it would seem that the necessity for a State-owned plant, as far as demand is concerned, might be analyzed on the bases:

1. That the construction of a new State plant is not justified in a State where the rated production capacity was greater than the demand during 1920.
2. Where the total demand in the State was less than, say, 400,000 barrels in 1920.
3. Where it can not be conservatively estimated that the demand for State business, year in and year out, will be practically steady.

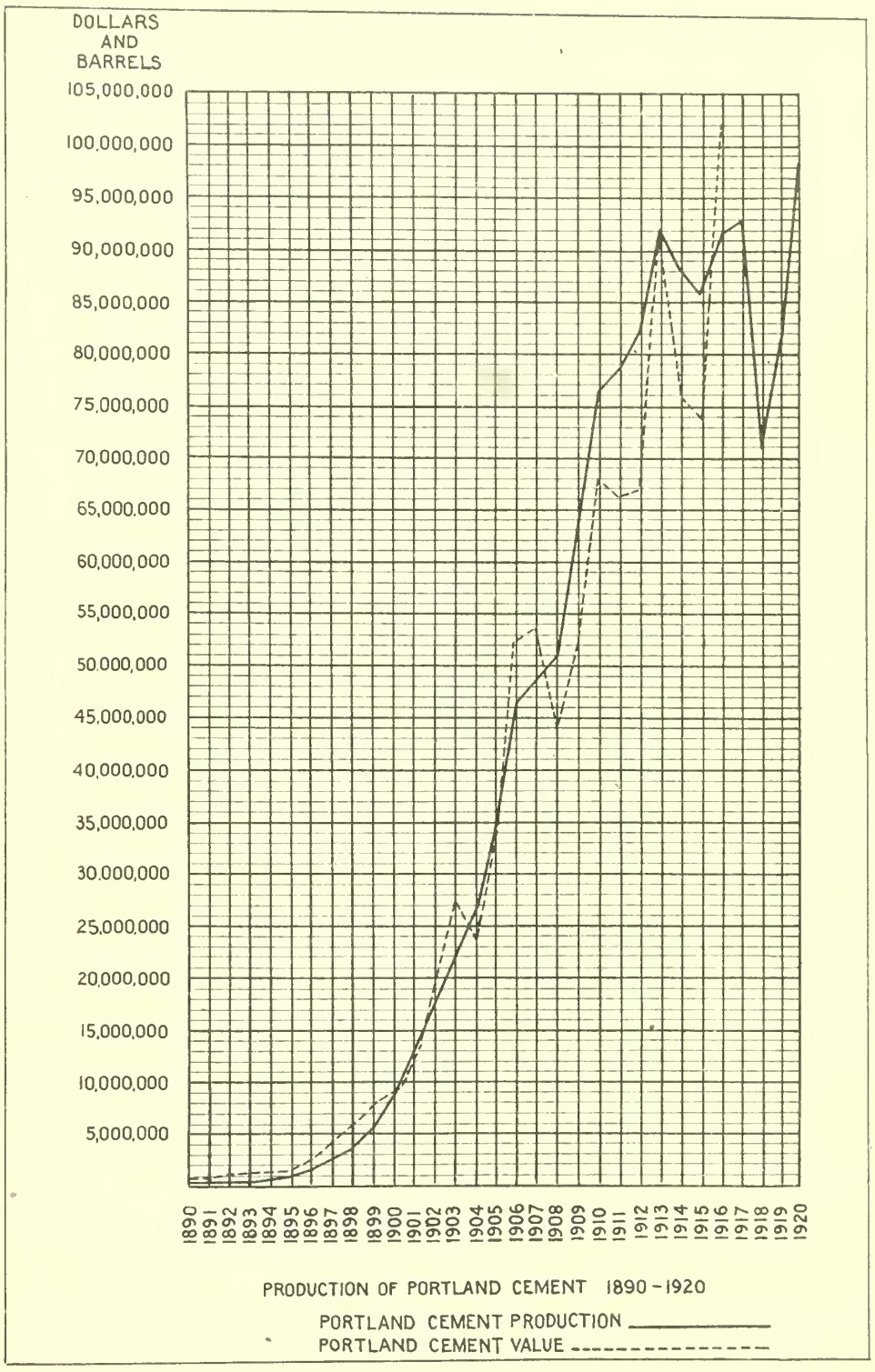


FIG. 1.—PRODUCTION OF PORTLAND CEMENT.

ENFORCING OPTIONS STABILIZES BUSINESS.

To obtain better service from the private cement plants it is most important that the States cooperate with the manufacturers to that extent. It is obvious that to operate any manufacturing plant intelligently and economically there must be at all times in the mind of the operator a reasonably clear idea of its obligations. Theoretically, whenever a company makes a sale it sets aside a certain quantity of its product to discharge the obligation under that sale. If a manufacturer should give an option on 100,000 barrels of cement to 100 customers he would be obliged to supply 10,000,000 barrels if every customer should enforce his option. The manufacturer, therefore, must keep himself in a position to supply that quantity of cement at the contract unit price. Conversely, if some or all of the holders of options should take less than the full quantity covered by their options, the manufacturer would have on hand a quantity of unsold cement which he, perhaps, could have disposed of elsewhere to advantage if he had known his outstanding options would not be enforced. This point is a most important one, involving, as it does, the manufacturer's relations with a large consumer such as a State highway department.

It is possible that even with the utmost of cooperation on the part of the State the problem of obtaining an adequate supply of cement at reasonable price will not be capable of solution without resorting to State ownership. But before we go to that extreme it would be well to exhaust all other means. To acquaint the producers, at least approximately, with the probable amount of our cement requirements, so that they will know what we will expect of them at least four months before they must begin delivering material, is one very important way in which we can aid in the solution of our own problems by utilizing the existing private agencies. In many States the present yearly cement requirements for State highway work are from 15 to 20 per cent of the total available production, and this percentage is required during the six months of heaviest demand. It is essential, therefore, that the manufacturer schedule his output so that the other customers shall receive as large a proportion of their requirements as possible during the months of minimum demand.

TABLE 3.—*Consumption of Portland cement by States.*

	Consumption (barrels, even thousands).					Consumption per capita (barrels).					Consumption (per cent).				
	1915	1916	1917	1918	1919	1915	1916	1917	1918	1919	1915	1916	1917	1918	1919
Alabama	385,000	458,000	468,000	840,000	577,000	0.17	0.20	0.20	0.35	0.24	0.46	0.50	0.53	1.23	0.7
Arizona	221,000	345,000	374,000	296,000	[1] 366,000	.89	1.35	1.42	1.09	1.31	.26	.38	.41	.43	.4
Arkansas	277,000	394,000	344,000	285,000	437,000	.16	.17	.19	.16	.24	.33	.32	.39	.42	.5
California	4,009,000	4,362,000	4,652,000	3,569,000	[1] 3,837,000	1.41	1.48	1.53	1.14	1.20	4.76	4.77	5.33	5.22	4.6
Colorado	543,000	657,000	763,000	583,000	679,000	.58	.68	.79	.57	.65	.64	.72	.87	.85	.8
Connecticut	1,645,000	1,623,000	1,455,000	936,000	1,273,000	1.34	1.30	1.15	.73	.97	1.95	1.78	1.66	1.37	1.5
Delaware	172,000	195,000	213,000	269,000	290,000	.81	.92	.99	1.24	1.32	.20	.21	.24	.39	.3
District of Columbia	443,000	340,000	514,000	611,000	408,000	1.23	.93	1.40	1.63	1.07	.53	.37	.58	.89	.4
Florida	486,000	484,000	523,000	363,000	506,000	.56	.54	.58	.39	.53	.58	.53	.60	.53	.6
Georgia	620,000	808,000	799,000	708,000	1,041,000	.22	.28	.28	.24	.35	.74	.88	.90	1.03	1.2
Idaho	243,000	523,000	466,000	233,000	[1] 297,000	.59	1.22	1.05	.50	.62	.29	.57	.53	.34	.3
Illinois	6,739,000	7,704,000	7,188,000	5,049,000	6,159,000	1.11	1.25	1.15	.80	.96	8.00	8.43	8.21	7.38	7.4
Indiana	2,954,000	3,749,000	3,408,000	2,503,000	3,134,000	1.06	1.33	1.20	.88	1.09	3.51	4.10	3.89	3.66	3.7
Iowa	3,637,000	3,918,000	3,507,000	2,334,000	3,402,000	1.64	1.76	1.57	1.05	1.53	4.32	4.28	4.01	3.41	4.1
Kansas	1,765,000	2,164,000	1,992,000	1,418,000	1,857,000	.98	1.18	1.08	.76	.98	2.10	2.37	2.28	2.07	2.2
Kentucky	828,000	878,000	769,000	630,000	770,000	.35	.37	.32	.26	.32	.98	.96	.88	.92	.9
Louisiana	778,000	599,000	613,000	588,000	578,000	.43	.33	.33	.31	.30	.92	.65	.70	.86	.7
Maine	440,000	352,000	376,000	247,000	342,000	.57	.46	.50	.32	.43	.52	.39	.43	.36	.4
Maryland	1,370,000	1,393,000	1,560,000	1,459,000	1,368,000	1.01	1.02	1.14	1.05	.98	1.63	1.52	1.76	2.13	1.6
Massachusetts	2,915,000	2,878,000	2,799,000	2,236,000	2,310,000	.80	.78	.74	.58	.59	3.46	3.15	3.20	3.27	2.8
Michigan	3,954,000	4,818,000	4,400,000	3,244,000	5,013,000	1.31	1.58	1.42	1.04	1.58	4.69	5.27	5.03	4.74	6.0
Minnesota	3,147,000	3,315,000	2,788,000	2,202,000	3,002,000	1.40	1.45	1.21	.94	1.26	3.74	3.62	3.19	3.22	3.6
Mississippi	195,000	246,000	251,000	165,000	257,000	.10	.13	.13	.08	.13	.23	.27	.29	24	.3
Missouri	2,896,000	2,785,000	2,539,000	1,644,000	2,209,000	.85	.82	.74	.48	.64	3.44	3.05	2.90	2.40	2.6
Montana	578,000	660,000	790,000	367,000	456,000	1.30	1.44	1.67	.76	.91	.69	.72	.90	.54	.5
Nebraska	1,253,000	1,439,000	1,466,000	1,072,000	1,451,000	1.00	1.13	1.14	.83	1.11	1.49	1.57	1.67	1.57	1.7
Nevada	43,000	44,000	77,000	34,000	50,000	.42	.41	.69	.30	.42	.05	.05	.09	.05	.0
New Hampshire	343,000	240,000	316,000	223,000	321,000	.78	.54	.71	.50	.72	.41	.26	.36	.33	.3
Jew Jersey	3,502,000	3,405,000	3,112,000	2,909,000	3,160,000	1.22	1.16	1.03	.94	1.00	4.16	3.72	3.56	4.25	3.8
New Mexico	253,000	180,000	175,000	135,000	132,000	.64	.44	.41	.31	.29	.30	.20	.20	.20	.
New York	10,381,000	10,233,000	8,915,000	6,335,000	7,317,000	1.03	1.00	.86	.60	.68	12.32	11.19	10.16	9.25	8.8
North Carolina	573,000	1,083,000	1,022,000	644,000	774,000	.24	.45	.42	.26	.31	.68	1.19	1.12	.94	.
North Dakota	247,000	415,000	411,000	272,000	352,000	.35	.56	.54	.34	.43	.29	.45	.47	.40	.
Ohio	7,081,000	7,603,000	6,992,000	4,861,000	6,415,000	1.39	1.48	1.34	.92	1.20	8.41	8.32	7.99	7.11	7.
Oklahoma	674,000	1,154,000	1,444,000	1,067,000	1,322,000	.32	.52	.63	.45	.54	.80	1.26	1.73	1.56	1.
Oregon	539,000	514,000	416,000	323,000	642,000	.67	.61	.48	.36	.70	.64	.56	.48	.47	.
Pennsylvania	7,328,000	7,486,000	7,770,000	6,606,000	7,717,000	.87	.88	.91	.75	.86	8.70	8.19	8.74	9.65	9.
Rhode Island	379,000	351,000	332,000	344,000	454,000	.63	.57	.53	.54	.70	.45	.38	.38	.50	.
South Carolina	273,000	459,000	502,000	710,000	531,000	.17	.28	.31	.43	.32	.32	.50	.57	1.04	.
South Dakota	433,000	562,000	538,000	419,000	713,000	.64	.80	.75	.57	.95	.51	.62	.61	.61	.
Tennessee	739,000	943,000	882,000	938,000	767,000	.33	.41	.38	.40	.33	.88	1.03	1.02	1.37	.
Texas	1,744,000	2,260,000	2,037,000	1,543,000	1,980,000	.40	.51	.45	.34	.42	2.07	2.47	2.32	2.26	2.
Utah	424,000	468,000	488,000	319,000	[1] 412,000	1.00	1.08	1.10	.70	.89	.50	.51	.56	.46	.
Vermont	210,000	199,000	180,000	122,000	174,000	.58	.55	.49	.33	.52	.25	.22	.21	.18	.
Virginia	1,181,000	1,105,000	1,341,000	2,054,000	1,477,000	.54	.50	.61	.92	.65	1.40	1.22	1.53	3.00	1.
Washington	1,037,000	1,288,000	1,187,000	1,043,000	1,277,000	.70	.84	.74	.63	.74	1.23	1.41	1.35	1.52	1.
West Virginia	1,070,000	995,000	1,181,000	1,277,000	1,089,000	.79	.72	.85	.89	.74	1.27	1.09	1.34	1.87	1.
Wisconsin	3,168,000	3,282,000	2,962,000	2,212,000	3,274,000	1.28	1.31	1.17	.87	1.27	3.76	3.59	3.38	3.24	3.
Wyoming	116,000	170,000	226,000	187,000	301,000	.68	.94	1.22	.98	1.54	.14	.19	.26	.27	.
Total	84,231,000	91,426,000	87,523,000	68,428,000	82,670,000	.84	.90	.85	.65	.77	100.00	100.00	100.00	100.00	100.

[1] Partially estimated.

Both the consumer and the producer must make increasing endeavors to stock and store materials, so that not only manufacturing plants but the transportation agencies as well can operate under normal working conditions.

LACK OF COOPERATION WILL INCREASE DIFFICULTIES.

The States which fail thus to cooperate and through secretiveness or lack of business judgment fail to notify the producers of their potential yearly requirements are apt to experience increasing difficulties in securing their supply of cement. Nor is the necessity for such anticipation of the requirements to be avoided by State operation. In fact, the necessity of it would then l greater because of the more restricted market of tl State plant, which could not dispose of surplus stoc outside of the State. For the efficient operation of tl State plant it would be necessary not only to know tl amount of the annual requirement but that the dema should be practically constant year after year; a even then, because of the seasonal variation in tl State's requirements, it would be necessary to bui large stock houses at the plant or to provide well-bu storehouses of considerable capacity on the contracts.

Worthy of mention also as means of stimulati supply are many intangibles, chief of which are the

lations of the manufacturer and consumer. The operations of a great industry are often considered by the uninitiated only as fit topics for police court investigations or as the particular prey of official investigation carried out along political or mercenary lines. It would seem that public officials should approach the problem of making available an increased supply of any basic construction material not by treating the industry as a positive menace to society—a profiteering class of business buccaneers who should be hammered unmercifully in order to force them to disgorge unwarranted profits,—but rather it would seem that a public official should and must, in these days of increasing responsibility, take the business man more closely into his confidence. For example, there is no reason why a broad-minded official interested in supplying a certain commodity for use on State contracts, whether the commodity be steel, oil, asphalt, brick, or cement, should assume that it is necessary to gather his statistics behind closed doors. By and large, most of our construction material manufacturing corporations are run on a broad-gauged business basis, and it is but fair to assume that our supply of these materials will be augmented only by close and consistent coöperation with those who make them. All of our industrial plants are business assets to our States, and individual initiative is best fostered by legitimate and friendly cooperation. Such cooperation must result in more efficient service and quicker dispatch of our public works programs.

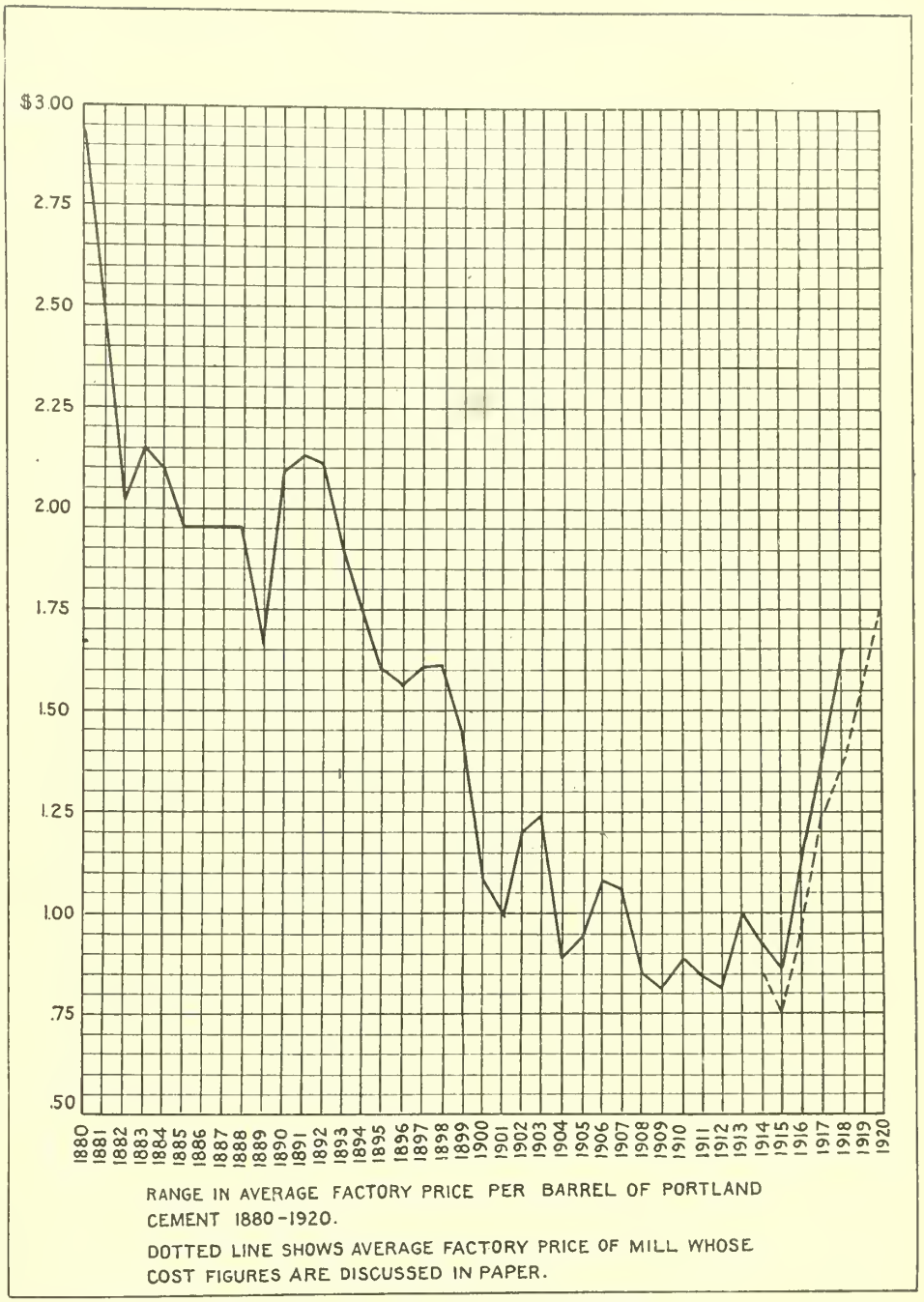


FIG. 2.—PRICE RANGE OF PORTLAND CEMENT.

In the preceding development the author has attempted to show the causes for the unsatisfactory conditions of the cement market and to suggest means by which an adequate supply of this essential material can be assured without turning from the existing commercial sources to the development of new Government-controlled plants. In view of the fact that the producing capacity of the existing plants has never been fully utilized, he is convinced that the difficulties can be ironed out in most cases by close cooperation of producer and consumer.

Where it appears that such is not the case, and that State operation is needed as a solution, there are a number of other facts which should be carefully considered before embarking on the project.

AVAILABILITY OF RAW MATERIALS.

One of the most important of these other matters is the question of availability of the raw materials. In many States all available supplies of the raw materials required are now either owned or under option, and there are several States in which there have been found no satisfactory materials in sufficient quantity to justify the construction of a plant. This is notably the case in the New England States, in Wisconsin, and in some of the Southern States. It is essential, therefore, be-

fore taking steps looking toward the construction of a plant, to determine that there is satisfactory raw material available at strategic locations and in sufficient quantity to enable the plant to operate continuously for a long term of years.

This means an appropriation to enable a geologist or cement expert to make an authoritative drill hole and quantity survey of any suggested locations. What is likely to happen if this step is omitted could be illustrated by the results in many cases where promoters of private plants have overlooked its importance in their enthusiasm, thereby making it necessary to transport either shale, clay, limestone, or silica rock long distances at material increases in the unit cost of production. In these days of increased transportation charges, this item might militate against the economical operation of a poorly located plant, inasmuch as over 600 pounds of raw materials and from 150 to 200 pounds of coal are required for the production of a barrel of cement.

DISTANCE FROM MARKETS.

Another feature which must be closely associated with the location of the plant is the distance to the area of largest consumption. The Lehigh Valley mills are adjacent to the New York and Philadelphia markets and tidewater, and the transportation charges to New England points are sufficiently low to enable the Pennsylvania manufacturer to compete with the neighboring New Jersey and New York mills. The western Pennsylvania mills are within easy distance of the Pittsburgh market; the Illinois mills are close to the Chicago market; the Texas mills to the El Paso, San Antonio, and Dallas markets. The California mills are within easy access of the San Francisco and Los Angeles markets as well as tidewater. Were a State-owned plant to be built, it should be located to serve the entire State, and the transportation situation must be carefully analyzed by a traffic expert who is thoroughly acquainted with traffic rates and charges. If this feature be forgotten, a mill might easily be located so that the freight differential would penalize the mill in an amount of from 25 to 60 cents per barrel for transportation. In Pennsylvania this differential for a plant centrally located might result in a loss of at least 30 cents per barrel for shipments to eastern and western points in the State. This element, on close analysis in States of large area, might make it advisable to consider the establishment of two small mills instead of one relatively large one.

The experts in the cement field closely follow the development of prospective sales fields, and every large cement manufacturing corporation employs men who are constantly exploring new territory, both with regard to the establishment of new plants and to increasing the radius of their sales fields. It is essential that every company keep their transportation rate contour investigations up to date inasmuch as this feature enters to a very great degree into the final unit costs and profits. The restriction of sales territory is common in every basic industry which has been susceptible of broad expansion inasmuch as new plants are being constantly established. The cement industry is perhaps the most striking example of this principle, due largely to widespread available raw materials.

COMPETITION BETWEEN STATE AND PRIVATE PLANTS.

Individual initiative would doubtless play a dominant part in the competition of State as against privately owned plants, and the probabilities are that were a State-owned plant to be built it would immediately become the target for intense competition on the part of the private plants in the field, which have through long experience introduced many economies in their process of manufacture. This competition would be particularly dangerous were the private corporations able to materially underbid the State plant. While it would seem unwise to draw general conclusions, still there have been instances where private corporations have been able to accomplish this, inasmuch as their sales field enables them to operate continuously, whereas the municipal or State-owned plant could only operate part time, and therefore uneconomically.

There are many conditions which would justify the construction of a State plant. For instance, there might be cases where existing plants continue to turn out a nonuniform product, due to inferior raw materials, or where due to poor location on the part of the original promoter, the private plant was placed far from available raw materials or the sales field. It must be stated, however, that private capital, conservatively managed, must sooner or later discover these weak private plants and eliminate them by legitimate business methods.

In analyzing competition it is essential that a survey be made of all private plants in the territory and that traffic-rate contours be determined. Further, it is suggested that the business of the competitors be analyzed as to life, volume, and what would be the effect of the State plant on adjusting the sales prices of private plants due to State competition. In the past there have been cases where sales territories of specific private plants have been made the dumping grounds for plants who could afford to dispose of parts of their product which strict interpretation of specifications had eliminated from their immediate sales field. This condition would not govern, however, in the case of the State plant, inasmuch as it must be assumed that all States have well-equipped laboratories, directed by experienced testing engineers, who pass upon the acceptability of the millions of dollars' worth of construction materials used by them every year.

CONDITIONS JUSTIFYING A STATE PLANT.

Were a State-owned plant to embark in business today it would do so in a period of relative uncertainty and of high prices, and the advisability of entering the

field must be based on a cold analytical examination which must unmistakably show that:

(1) Competition is lacking.
(2) The existing price scale is too high.
(3) The available product is inferior.
(4) The privately owned plants are woefully lacking in cooperation.
(5) The capacity of the existing plants is not sufficient to supply the demand, assuming transportation facilities normal.

Economically, the broad general condition of the cement industry to-day is conducive to keen competition. As has been pointed out previously, the industry has never been able to market over probably 75 per cent of its capacity, although in specific State fields this percentage may run higher.

While there may be irrational statements given out regarding excessive prices and frozen competition, we must not forget that American business to-day is open to the analytical eye of an omnipresent government, which through its several departments has full authority to not only scan the books of every commercial enterprise, but has also the right to make the most searching investigations regarding the trade relations of all plants turning out a basic product. It would seem that we must differentiate the purposes of such trade investigations as may form the basis of highly colored newspaper reports because many such investigations are not investigations in the true sense of the word. The investigations I have in mind are those of which we hear but little and which are carried out quietly and purposely to correct glaring irregularities either in the financial or trade relations of existing corporations.

Unfortunately, engineers, as a rule, are not always conversant with the cost of manufacturing the materials they use, and I believe that we are safe in saying that generally the engineer has no clear conception of the cost of manufacturing cement. In discussing the price scale, an endeavor will be made a little later to analyze the cost entering into the manufacture of this product, and you may then be able to draw your own conclusions regarding the business hazard encountered in placing this material on the market.

Eventually an inferior product is eliminated due to lack of confidence in the product on the part of the consumer. It would seem that inferior cement is now the exception rather than the rule, and we should understand that the product in its various stages through the mill is under the direct control of the chemist, and further, that it has been found economical and essential that manufacturing methods be gradually extended and refined in order to cheapen the cost of production and, therefore, the cost to the consumer. Strict control on the part of the chemist elminates the manufacture of an inferior product, and thus eliminates wasted effort and financial loss to the manufacturer. It is a common occurrence for many new mills to run for weeks before the chemist is finally able to control the finished product. Many cases have occurred where it has been necessary to remodel or change the system of manufacture so that conditions which were not foreseen or properly interpreted by the designer might be remedied. Among these might be mentioned the color of the product, its setting qualities, its fineness, and its soundness. It is also common in many mills to find instances where the different units were not properly correlated, the crushing plant would not deliver enough raw materials to permit of continuous operations of all the kiln units, the kiln units would not deliver the clinker fast enough to keep the grinding department in continuous operation, or the power plant was not sufficiently flexible to adapt itself to the changing loads required for economical operation. These conditions in many instances have proved to be financially burdensome.

It would seem desirable again to call attention to cooperation between the manufacturer and the State as a consumer of cement. On the part of the State it would seem that this neglect might be due to a fancied belief that the taxpayers would think that a public official was dominated by certain commercial motives and that he was not actuated by high regards in giving his best efforts in handling the program for which he is held responsible. It would seem that if highway engineers expect to carry out the tremendous responsibility which has been thrust upon them, and which must be carried to a successful conclusion, they must so carry out their work that it will bear the closest scrutiny of the public, and this can no better be consummated than by allowing the manufacturer of all products to know what the State requirements will be in advance. The poorest cooperation that a manufacturer can give consists, first, in poor service; second, malicious promises that he will deliver on contracts which he knows he can not fulfill; third, the sale of his product when he does not know the true cost of manufacture, the last fault being economically the greatest because sooner or later it must result in bankruptcy for his company and the general unsettlement of society. The history of the cement industry is replete with glaring examples of financial failures, and a great many of the companies now in existence have passed through bankruptcy. There have been many cases where promotional schemes have been fostered, plants built, only to pass completely to the junk pile or to become eyesores to those who had invested their savings in them. I repeat, that the poorest cooperation a manufacturer of any commodity can give the purchasing public is that of selling his product at a price below the cost of production or of so running his business as to grant undue extension of credits.

WHAT IS A FAIR PROFIT?

Selling any product at a price which will net an exorbitant profit is economically unsound and will ultimately limit the use of that product. It is interesting to note in this connection that the great war revealed real weaknesses in many of our industrial enterprises.

During the strenuous times of 1917 and 1918 it became necessary for the Federal Government to closely analyze our producing capacity, and it became increasingly evident that Federal price regulation was essential to our early and successful completion of the great venture. Hearings were held in Washington continuously before the Federal Trade Commission, the War Industries Board, and many other commissions organized to solve our manufacturing difficulties. The books of many manufacturing industries were opened to close scrutiny. It is interesting to note that the hearings as they involved the cement industry developed the fact that there were but four cement manufacturing companies in this country that had fallen within the excess-profits tax provision.

In marketing Portland cement the general practice in many parts of our country is to sell the product to the consumer through legitimate dealers. In opening this phase of the marketing problem it would seem that whenever a dealer does an actual service he is entitled to a fair and just profit. We will all admit that the dealer does a real service by using his yards as a small storage supply base and many times in assuming the consumer's credit obligations until such time as the consumer chooses to pay for the product. In public works, however, this reasoning does not seem to hold. On road contracts very little of the cement purchased through dealers goes through the dealers' yards, and the dealer does not perform a real service in carrying the credit load of a contractor. Many contractors are discounting their bills with regularity in the 10-day period, and they pay net for the product within the customary 30 days. It would seem desirable, therefore, that the States, as large consumers of cement, should be entitled to more consideration from the manufacturers and that cement used for State work should be available at a price equal to that paid by all dealers. On further analysis, we should bear in mind that a complete discussion of the subject would warrant us in assuming that a State should not place upon the manufacturer the burden of carrying an undue credit load or a load of commitments on which he can not hope for financial return for periods of from five to six months. The argument might be raised that this is one of the manufacturer's hazards. If it is a hazard, what would be his fair remuneration for carrying it, or what would be a legitimate method to be used by a State in guaranteeing to the manufacturer the prompt or eventual settlement for materials which he has furnished?

COST OF CONSTRUCTION AND OPERATION OF PLANTS.

Taking into consideration the conditions which have been developed, it would seem that obviously the only justification for the erection of a State-owned plant is failure in the past, or probable failure in the future, to secure sufficient cement for the State's needs and at reasonable prices for the territory in which the plant would be located.

Specifically, the question resolves itself into two parts:

First. Does a real need for a State-owned plant exist in a given State after the subject has been thoroughly analyzed from the viewpoint which has been expressed in this paper?

Second. What will be the cost to construct and operate a plant of the required capacity?

It will be assumed that the development covered in the first topic warrants a close analysis of topic number two, and that it has been decided that close estimates be prepared for the erection of—

(1) A first-class cement plant of 600,000 barrels capacity per year, assuming an operation period of 350 days per year. The plant is to be so designed that there will be minimum maintenance requirements, and to be equipped with raw materials storage bins, up-to-date dust-collecting systems, waste-heat boilers, a central generating plant with all machinery supplied with unit electric-driven motors. It is further assumed that a sanitary system, a pumping station, and a cement stock house of 150,000 barrels capacity, a main office building, dispensary, and sufficient trackage to facilitate train movements, both from and to the mill, will be required. It is further assumed that the mill will be located on property purchased by the State on which there is a sufficient raw material supply to run the plant from 50 to 100 years. The estimates to include, also, general items which are necessary in financing the construction, with sufficient capital to be laid aside to operate the plant for one month. The operation expenses are to include sufficient sack supply for three months' operation.

(2) A second-class plant of the same capacity built with a view to detailed structural maintenance from time to time, and with dust-collecting systems, sanitary system, dispensary, etc., eliminated.

Such an estimate is given in detail in Table 5. This estimate is for plants which will be erected on the assumption that the State believes that the demand for cement has become stabilized and that the industry is one of the major construction industries; that the plant must be prepared to turn out cement which will be subject to intense competition, and therefore, be manufactured at the lowest possible mill cost. This estimate is for a contemplated plant in the north central or northeastern part of our country. The total cost per barrel of production for plant No. 1 is estimated to be $4.865 per barrel; for plant No. 2, $3.483 per barrel.

In order to operate these plants, it is assumed that the inventory given in the table will be necessary. This inventory amounts to $0.365 per barrel capacity. The total cost of construction and inventory is, therefore. $5.23 per barrel capacity for plant No. 1 and $3.848 per barrel capacity for plant No. 2.

TABLE 4.—*Mortality table, being average estimated life of various properties in the cement industry.*

	Average life (years).
Machinery:	
Quarry	
Locomotives	13
Tracks and cars	9
Steam shovels	11
Dredges	11
Drills—Well	9
Drills—Tripod	7
Live stock	8
Carts and wagons	7
Cableway	9
Raw department:	
Crushing machinery	14
Driers—Upright	11
Driers—Rotary	11
Slurry tanks	16
Grinding machinery	13
Clinker-burning department:	
Kilns	13
Coolers—Upright	12
Coolers—Rotary	13
Clinker-grinding machinery	12
Coal mill:	
Driers	11
Grinding machinery	14
Power house:	
Boilers	15
Engines	17
Generators	16
Motors	14
Stock-house machinery	10
Machinery and B. S. shop machinery	15
Buildings:	
Mill—	
Concrete	50
Steel and corrugated iron	20
Steel and stucco	21
Steel and brick	30
Timber	20
General (mill office, laboratory, storehouse, etc.):	
Concrete	50
Steel and corrugated iron	20
Steel and stucco	22
Steel and brick	30
Frame	18
Frame and stucco	22
Dwellings:	
Concrete	50
Brick	30
Frame	20
Frame and stucco	23

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920).*

	First-class plant—estimate.	Second-class plant—estimate.
General mill expense:		
Clearing, grading, and filling	$5,000	$3,000
Clock house and watchman's shanty	10,000	6,000
Fence, inclosing mill property	10,000	5,000
Total	25,000	14,000
Construction equipment:		
Tools and equipment	50,000	15,000
Temporary buildings	7,500	2,500
Temporary tracks	7,500	2,500
Total	65,000	20,000
Trestle to raw-material bins:		
Excavating and back filling	3,000	1,500
Foundations	10,000	2,000
Trestle	50,500	20,000
Walks	1,500	500
Total	65,000	24,000
Raw-material bins:		
Excavating and back filling	1,500	500
Foundations and floor	5,000	1,000
Building	37,000	7,000
Roof	3,500	1,500
Concrete walls and plastering	13,000	2,000
Total	60,000	12,000
Raw-material mill:		
Excavating and back filling	5,000	2,500
Foundations and floor	30,000	15,000
Building, hoppers, and upper floors	65,000	30,000
Roof	6,000	2,500
Walls, plastering, doors, and windows	15,000	5,000
Crushing machinery	7,000	7,000
Driers, stacks, and coal-burning apparatus	36,000	35,000
Dust-collecting system for driers	15,000	15,000
Preliminary grinding machinery	36,000	36,000
Tube mills	70,000	70,000
Elevating and conveying machinery	40,000	25,000
Dust-collecting system for machinery	15,000	15,000
Total	340,000	258,000

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920)*—Continued.

	First-class plant—estimate.	Second-class plant—estimate.
Raw-material storage bin:		
Excavating and back filling	$2,000	$1,200
Foundations, tunnels, and floors	4,000	2,000
Building	10,000	6,000
Roof	500	300
Concrete walls and plastering	7,500	2,500
Elevating and conveying machinery	6,000	6,000
Total	30,000	18,000
Gypsum storage:		
Excavating and back filling	500	200
Foundations and floors	2,000	600
Building, walls, and plastering	10,000	3,000
Roof	500	200
Elevating and conveying machinery	3,000	3,000
Total	16,000	7,000
Cement stock house (150,000 barrels capacity):		
Excavating and back filling	8,000	5,000
Foundations, tunnels, and floor	75,000	50,000
Building and hoppers	20,000	15,000
Concrete walls and plastering	142,000	60,000
Elevating and conveying machinery	30,000	30,000
Packing and loading machinery	15,000	15,000
Dust-collecting system	10,000	10,000
Total	300,000	185,000
Sack-storage building:		
Excavating and back filling	2,000	500
Foundation and floor	12,000	6,500
Building, walls, and plastering	25,000	15,000
Heating, lighting, and sanitary system	6,000	5,000
Bag-cleaning machinery	15,000	15,000
Dust-collecting system	15,000	13,000
Total	75,000	55,000
Machine and blacksmith shop:		
Excavating and back filling	500	200
Foundation and floor	5,500	3,000
Building	18,000	8,000
Roof	3,000	1,000
Walls, plastering, doors, and windows	8,000	4,000
Heating and sanitary system	8,000	6,800
Machinery and equipment	17,000	17,000
Total	60,000	40,000
Coal Bins:		
Excavating and back filling	500	100
Foundations and floors	2,000	1,000
Building	16,000	8,000
Roof	500	300
Concrete walls, bin floor, and plastering	6,000	3,600
Total	25,000	13,000
Coal-grinding building:		
Excavating and back filling	1,500	500
Foundations and floors	8,000	3,000
Building and hoppers	16,000	10,000
Roof	1,500	500
Crushing and drying machinery	12,000	12,000
Pulverizing machinery	14,000	14,000
Dust-collecting system	9,000	8,000
Elevating and conveying machinery	8,000	8,000
Total	70,000	56,000
Burner building:		
Excavating and back filling	3,000	1,000
Foundations and floor	15,000	8,000
Building, hoppers, and upper floors	35,000	25,000
Roof	3,500	1,000
Walls, plastering, doors, and windows	11,000	6,000
Two 10 by 150 foot kilns and stack bases	100,000	80,000
Dust-collecting system for kilns	105,000	.....
Elevating and conveying machinery	17,500	17,000
Total	290,000	138,000
Waste-heat boiler house:		
Excavating and back filling	1,500	500
Foundation and floors	7,500	3,500
Building and upper floors	19,000	10,000
Roof	500	300
Walls, plastering, doors, and windows	7,500	3,500
3 boilers, settings, and superheaters (2 waste heat, 1 coal fired)	90,000	90,000
Flues to and from boilers and fans	7,500	7,500
Fans, motors, and switches	16,000	16,000
Boiler-feed pumps, motors, and switches	7,500	7,500
Boiler-feed water piping	10,000	8,000
Boiler-feed water, filtrating, and softening plant	5,000	5,000
Blow-off piping	4,500	3,000
Steam line, supports, and covering	23,500	20,200
Total	200,000	175,000

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920)*—Continued.

	First-class plant—estimate.	Second-class plant—estimate.
Storeroom:		
Excavation and back filling	$500	$100
Foundation and floor	2,500	1,500
Building, walls, and plastering	9,000	6,000
Equipment	3,000	2,400
Total	15,000	10,000
Sanitary installations:		
Excavating and back filling	500	
Foundation and floors	5,000	
Buildings	12,500	
Roofs	2,000	
Walls, plastering, doors, and windows	7,000	
Plumbing, lighting, and heating systems	8,000	5,000
Total	35,000	5,000
Main office, foremen's office, and dispensary:		
Excavating and back-filling	2,000	500
Foundation and floors	10,000	3,500
Building, walls, plastering, doors, and windows	40,000	10,000
Heating, lighting, and plumbing system	3,000	2,000
Furniture and fixtures	10,000	8,000
Total	65,000	24,000
Compressed-air system:		
Air compressor and motor	4,500	4,500
Air receiver and piping	4,500	4,500
Total	9,000	9,000
Track system: Tracks	120,000	100,000
Drainage and sewer system	10,000	3,000
Quarry:		
Steam shovels	30,000	20,000
Quarry car and dinkey locomotive	55,000	40,000
Crushing plant, complete	90,000	90,000
Total	175,000	150,000
Generating station:		
Excavating and back filling	3,000	1,200
Foundations and floor	12,000	5,500
Building and upper floors	19,000	11,000
Roof	1,500	500
Walls, plastering, doors, and windows	12,000	8,000
Motor generator	6,000	6,000
Sanitary facilities	500	300
Turbo-generator and exciter (two 1,000-kilowatt units; one 1,000-kilowatt, spare)	85,000	85,000
Condensor and accessories	10,000	10,000
Condensor piping	9,000	8,500
Air washer	2,000	2,000
Transformers	15,000	15,000
Main switches, switchboard, and wiring	15,000	15,000
Total	190,000	168,000
Electrical work outside station:		
Trenching and back filling	2,000	500
Concrete work and wire ducts	18,000	11,500
Wiring	35,000	25,000
Total	55,000	37,000
Pumping station:		
Excavating and back filling	500	100
Foundation and floors	2,500	1,500
Building	3,000	2,000
Roof	250	150
Walls, plastering, doors, and windows	1,500	1,000
Pumps, motors, and switches	6,000	6,000
Water piping, valves, and fittings	24,000	20,000
Screens	2,250	2,250
Total	40,000	33,000
Clinker storage:		
Excavating and back filling	3,500	1,000
Foundations, retaining walls, and floor	22,500	15,000
Crane runway	15,000	12,000
Clinker cranes, with grabs	34,000	34,000
Total	75,000	62,000
Finishing mill:		
Excavating and back filling	2,500	1,000
Foundations and floor	20,000	12,000
Building, hoppers, and bridge to stock house	60,000	45,000
Roof	2,500	1,000
Walls, plastering, doors and windows	15,000	10,000
Preliminary grinding machinery	35,000	35,000
Tube mills	70,000	70,000
Elevating and conveying machinery	30,000	30,000
Dust-collecting system	25,000	20,000
Total	260,000	224,000
Plant property:		
Stone property, 150 acres; shale property, 50 acres; plant property, 50 acres	125,000	125,000
Total	2,795,000	1,965,000

TABLE 5.—*Estimate of cost of a 600,000-barrel cement plant (Dec. 9, 1920)*—Continued.

	First-class plant—estimate.	Second-class plant—estimate.
General works expense	$30,000	$30,000
Engineering	45,000	45,000
Contingencies	25,000	25,000
Accident and hospital reserve	25,000	25,000
General overhead expense, 4.5 per cent	125,000	125,000
Grand total	2,920,000	2,090,000

$2,920,000 divided by 600,000 equals $4.865 per barrel (first-class plant).
$2,090,000 divided by 600,000 equals $3.483 per barrel (second-class plant).

Estimated cost of these cement plants having a yearly capacity of 600,000 barrels, based on 350 days' operation and on the supposition that the plant site is level ground with water and railroad facilities adjacent to the site. The above first-class plant is equipped with all modern and up-to-date improvements such as waste-heat boilers, dust-collecting apparatus throughout, and modern sanitary facilities.

Inventory needed in the operations of a 600,000-barrel capacity plant.

	First-class plant estimate.	Second-class plant estimate.
600,000 sacks at $150 per thousand (6 months' supply)	$90,000	$90,000
Stores and miscellaneous supplies	40,000	40,000
2,500 tons coal at $5 (1 month's supply)	12,500	12,500
250 tons gypsum at $7 (1 month's supply)	1,750	1,750
Raw material, limestone, shale, or clay	5,000	5,000
10,000 barrels clinker (average monthly inventory $1)	10,000	10,000
40,000 barrels cement (average monthly inventory $1.50)	60,000	60,000
Total	219,250	219,250

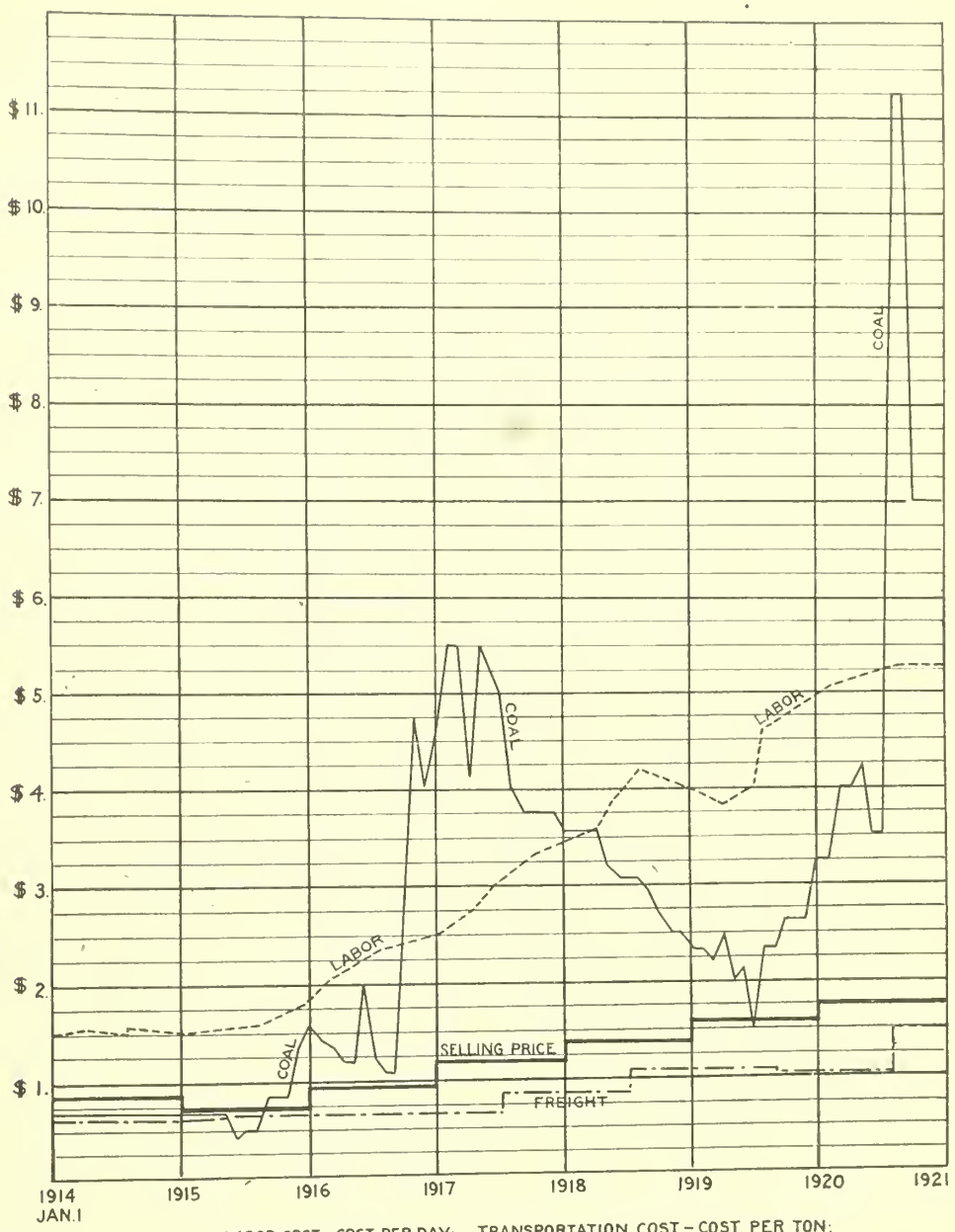
For larger mills the cost of construction will be somewhat smaller. An estimate for a million-barrel mill of type No. 1 would be from $4.50 to $4.75 per barrel capacity. The estimate does not provide for financing the housing of employees. If the mill is located near a town and convenient transportation is available the housing problem may solve itself. If, however, the mill is at some distance from a town, it would probably become necessary to establish a village which would contain some 500 to 600 people, requiring at least from 75 to 100 houses, with the necessary church, school, stores, and some sort of municipal improvements. No attempt will be made to estimate the cost of this feature, although it must be given consideration in order to insure continuous and economical operation of the plant. Developments durings the years 1916 to 1920 have demonstrated to cement manufacturers that this feature is essential for the economic operation of plants. A State-owned plant must be operated continuously or its operating costs will mount to figures which would not permit of competition.

It will be assumed that the next step in analyzing the subject will be to estimate the operating costs of the projected plant, which will be erected following the outline as given for plant No. 1. It should be understood that the system used to figure an estimated unit cost of production must approximate the true cost of production. Otherwise, if the actual operating cost is higher and becomes excessive, the venture may result in either loss of capital or loss of sales. If the manufacturing costs are understated, the profits will be overstated; and, conversely, if the manufacturing costs are overstated, and the mill produces with regularity and economy, the venture will be profitable. True costs must reflect seasonal fluctuation in

production, shutdowns, strikes, overproduction of clinker or finished cement, poor transportation, and all favorable or unfavorable developments. A true estimate must also be made of labor efficiency.

Table No. 6 represents a close survey of 51 cement manufacturing plants and demonstrates the relative labor efficiency in both large and small mills.

Having in mind the operation of the projected plant, Table No. 7 gives an estimate of unit costs of operation and Table No. 8 represents the balance sheet of the projected company at the end of the first month's operation, the estimate being for December, 1920. It should be understood that the estimated costs, as given in these tables, are for a particular 600,000-barrel mill in a given section of our country, which will be subject to certain assumed operating conditions. The costs would not be applicable for a mill to be erected on the Pacific Coast or in the Southern States, where the operating conditions and the rate of consumption per month would be entirely different.



LABOR COST – COST PER DAY; TRANSPORTATION COST – COST PER TON; COAL COST – COST PER TON; SELLING PRICE PER BARREL OF CEMENT OF MILL QUOTED IN FIGURES NOS. 18 AND 19.

FIG. 3.—FACTORS IN COST OF PORTLAND CEMENT PRODUCTION.

TRUE COSTS OF AN OPERATING COMPANY.

To demonstrate the fluctuation in operating conditions, costs of materials, increased cost of transportation, and all of the many items which have entered into the true cost of cement during the past several years, Tables 9 and 10 are given for two mills of 2,000 and 3,900 barrels per day capacity, respectively. These mills have operated under the same management from 1915 to date. The company markets a well-known brand under an exceptionally able business management and has accepted its obligations of fulfilling holdover contracts from previous years, even at increasing manufacturing unit costs per barrel.

The smaller mill, with the higher unit cost per barrel, was shut down during 1918 and 1919, when the demand was far below production in this country and when we experienced general unsettlement in the construction industry. It will be noted that in the 3,900-barrel mill the cost of materials jumped from 20.6 cents per barrel in 1914 to 63 cents per barrel for the first 10 months in 1920; labor jumped from 6 cents to 13.7 cents per barrel; supplies from 6 cents to 12.7 cents per barrel; general mill expenses from 11.1 cents to 20 cents per barrel; reserves and packing costs from 17.5 cents to 22 cents per barrel.

A survey of some of the variable items entering into the manufacturing costs is given in figure 3. Freight is the average cost per ton from a given manufacturing plant to an assumed destination at a relatively short distance from the mill; the labor curve represents the average price of common labor employed at the mill; the coal cost represents quotations at mines or of spot coal during the tight period of midsummer 1920. The curve of selling price of cement is taken from the mill referred to in Tables 9 and 10.

TABLE 6.—*Labor efficiency in 51 cement plants, on man-hours per barrel basis, for the year 1919.*

Plant No.	Number of barrels produced.	Number of man-hours per barrel produced.															Number of barrels shipped.	Number of man-hours per barrel shipped.			Number of shifts in plant.
		Quarrying.	Raw department.	Clinker department.	Finishing department.	Power department.	Coal mill.	Yard.	Shops.	Repair gang.	Mill office.	Storeroom.	Laboratory.	Superintendent and general foreman.	Watchmen.	Miscellaneous.	Total.		Packing and loading.	Sack handling.	Total.	
1	855,463	0.112	0.075	0.072	0.048	0.041	0.027	0.030	0.064	0.058	0.030	0.013	0.025	0.037	0.009	.....	0.643	932,145	0.065	0.047	0.112	3
2	919,192	.317	.162	.083	.072	.132	.050	.018	.056	(1)	.022	.023	.030	.047	.010	.....	1.022	981,072	.102	.029	.131	2
3	406,000	(2)	.182	.090	.105	.034	.072	.052	.046	(3)	.015	.007	.025	.041	.014	.....	.683	483,450	.046	.034	.080	2
4	281,811	.042	.327	.103	.120	.156	.119	.165	.094	.084	.025	.013	.050	.035	.016	.....	1.349	284,686	.097	.023	.120	2
5	645,870	.170	.026	.038	.035	.027	.030	.068	.026	.033	.011	.010	.026	.015	.007	.....	.523	657,870	.055	.027	.082	2
6	400,000	.119	.071	.042	.054	.036	.036	.060	.030	.035	.020	.005	.025	.012	.....	.....	.545	344,000	.045	.022	.067	3
7	601,333	.096	.105	.057	.063	.075	.062	.097	.006	.185	.050	.033	.022	.023	.013	.....	.888	611,359	.066	.061	.127	2-3
8	1,414,000	.169	.041	.032	.061	.068	.025	.035	.064	.027	.021	.008	.018	.010	.010	.....	.590	1,638,582	.114	.054	.168	3
9	225,118	.426	.067	.023	.058	.038	.037	.047	.023	.023	.023	(5)	.029	(5)	.019	.....	.814	182,838	.079	.031	.110	3
10	600,000	.117	.106	.040	.040	.092	.045	.033	.100	.145	.028	.011	.043	.033	.007	.....	.840	650,000	.062	(6)	.062	2
11	352,130	.235	.196	.076	.074	.153	.027	.088	.085	.105	.009	.026	.044	.039	.....	0.038	1.195	417,896	.073	.019	.092	2
12	200,521	.494	.125	.115	.118	.147	.088	.100	.123	.118	.031	.065	.082	.055	.022	.....	1.683	189,668	.115	.058	.173	2
13	498,816	.251	.229	.111	.095	.018	.054	.145	.059	.132	.030	.029	.043	.051	.010	.....	1.257	608,707	.106	.080	.186	2
14	278,300	.208	.146	.104	.042	.031	.062	.006	.153	.089	.010	.016	.021	.043	.016	.....	.947	270,300	.072	.046	.118	2
15	547,771	.175	.215	.119	.135	.141	(7)	.069	.020	.015	.023	.014	.020	.014	.015	.023	.999	549,310	.083	.120	.203	2
16	498,781	.109	.094	.092	.065	.115	.059	.127	.058	.069	.020	.016	.014	.027	.....	.140	1.006	571,055	.071	.021	.092	2
17	838,056	.093	.128	.011	.044	.068	.042	.074	.056	.118	.016	.015	.017	.014	.011	.....	.707	998,676	.072	.027	.099	2
18	148,692	.350	.101	.117	.154	.213	.097	.046	.117	.254	.050	.023	.035	.043	.016	.....	1.617	180,688	.087	.025	.112	2
19	234,537	(2)	.238	.171	.112	.184	.095	.017	.050	.072	.037	.016	.041	.040	.018	.018	1.109	227,953	.066	.033	.099	2
20	697,286	.232	.081	.033	.067	.085	.033	.024	.026	.245	.008	.014	.029	.009	.006	.....	.892	707,836	.059	.071	.130	2
21	176,245	(2)	.196	.056	.132	.018	.097	.044	.073	.173	.016	.015	.046	.057	.013	.002	.938	179,928	.065	.034	.099	2
22	790,583	.135	.057	.052	.070	.110	.033	.033	.183	.187	.008	.011	.029	.012	.006	.002	.940	758,744	.113	6.005	.118	2
23	1,182,971	.105	.064	.030	.069	.033	.026	.009	.070	.123	.005	.009	.015	.008	.005	.002	.572	1,282,680	.068	6.001	.069	2
24	265,830	.308	.088	.072	.118	.135	.058	.067	.129	.333	.023	.019	.031	.026	.018	.004	1.429	370,652	.092	6.008	.100	2
25	513,448	.237	.131	.038	.073	.099	.031	.054	.092	.164	.018	.010	.029	.022	.009	.013	1.020	565,092	.100	6.008	.108	2
26	847,710	.164	.064	.046	.048	.063	.034	.073	.046	.055	.007	.007	.019	.008	.006	.....	.614	878,092	.061	(6)	.061	2-3
27	639,535	.118	.062	.059	.030	.031	(8)	.061	.037	.045	.044	.011	.027	.012	.007	.093	.638	659,642	.049	.016	.065	2
28	327,065	.097	.120	.107	.061	.099	(8)	.054	(9)	(9)	.024	.010	.036	.029	.012	.....	.649	355,977	.035	.028	.063	2
29	878,266	.307	.248	.079	.064	.107	.041	.078	.095	(10)	.020	.026	.039	.034	.013	.....	1.150	871,966	.067	.034	.101	2
30	1,118,625	.069	.072	.055	.045	.010	.002	.106	.038	.039	.022	.009	.027	.003	.008	.....	.551	1,121,400	.082	.079	.161	2-3
31	326,954	.266	.146	.068	.111	.026	.053	.034	.107	.122	.009	.011	.034	.044	.006	.....	1.038	357,304	.090	.045	.135	2
32	544,309	.165	.197	.043	.115	.013	.026	.093	.143	.038	.026	.005	.031	.020	.014	.....	.930	496,552	.143	.066	.209	2-3
33	377,000	.254	.056	.039	.052	.022	.034	.079	.048	.031	.022	.009	.024	.019	.010	.....	.699	379,011	.061	.067	.128	2-3
34	594,009	.199	.127	.056	.122	.015	.049	.025	.069	.011	.014	.007	.025	.013	.009	.....	.737	649,384	.058	.034	.092	2-3
35	717,410	.211	.111	.046	.046	.080	.029	.083	.126	.079	.003	.012	.013	.007	.003	.....	.840	742,641	.068	.074	.142	2-3
36	768,755	.365	.239	.070	.098	.012	.049	.011	.158	.008	.015	.022	.033	.019	.....	.....	1.088	948,672	.099	.027	.126	2
37	656,469	.302	.138	.116	.083	.048	.065	.084	.054	.054	.015	.026	.039	.022	.....	.....	1.047	664,224	.099	.065	.164	2
38	1,671,125	.129	.075	.042	.048	.085	.021	.032	.184	.136	.003	.003	.004	.021	.006	.217	1.006	1,563,161	.135	.078	.213	3
39	532,354	.408	.082	.051	.046	.090	.018	.324	.148	.059	.052	.013	.019	.033	.008	.....	1.351	643,535	.066	.078	.144	3
40	1,291,730	.165	.108	.016	.046	.049	.024	.126	.167	.050	.014	.007	.010	(10)	.007	.....	.789	1,391,096	.084	.062	.146	3
41	1,103,013	.218	.141	.031	.157	.117	.060	.043	.073	.079	.026	.009	.016	(10)	.....	.....	.970	1,466,398	.110	(10)	.110	2
42	1,099,399	.110	.080	.044	.038	.082	.031	.060	.096	.028	.020	.007	.017	.016	.015	.....	.642	1,299,566	.064	.044	.108	3
43	1,289,482	.133	.056	.028	.048	.057	.024	.030	.072	.084	.007	.007	.007	.011	.003	.....	.567	1,541,340	.041	.011	.052	3
44	698,601	.144	.130	.113	.122	.092	.066	.022	.010	(11)	.040	.068	.012	(10)	.013	.....	.833	867,526	.042	.005	.047	3
45	311,118	.442	.155	.075	.115	.194	.050	.012	.101	.303	.015	.025	.020	.022	.023	.....	1.551	347,481	.037	.010	.047	2
46	641,488	.375	.138	.058	.104	.152	.043	.009	.068	.106	.021	(10)	.015	(10)	.....	.....	1.091	705,825	.046	.010	.056	2
47	628,386	.353	.160	.077	.076	.181	.063	.056	.046	.204	.036	.008	.030	.010	.007	.....	1.309	663,509	.158	.048	.206	3
48	194,153	.148	.152	.063	.049	.014	.054	.038	.144	.046	.049	.013	.046	.063	.015	.....	.896	261,120	.047	.055	.102	3
49	333,483	.138	.114	.109	.094	.106	.053	.075	.043	.036	.036	.010	.032	.021	.010	.....	.879	338,278	.085	.045	.130	2
50	1,249,500	.059	.103	.039	.048	.039	.019	.097	.040	.114	.017	.004	.015	.021	.015	.....	.632	1,245,308	.057	(6)	.057	1
51	330,729	.090	.092	.065	.074	.130	.055	.138	.028	.055	.006	.009	.030	.028	.002	.....	.802	429,984	.048	.024	.072	1

[1] Repair gang distributed daily in other items.
[2] Purchase raw materials.
[3] Repair gang included in other departments.
[4] Purchase limestone.
[5] Man-hours for storeroom and superintendence not given.
[6] Bag cleaned by contract.
[7] Oil used for burning; man-hours for handling same insignificant.
[8] Oil used for burning.
[9] Always carried against departments.
[10] Man-hours not given.
[11] Repairs carried by each department.

TABLE 7.—*Statement of monthly costs for December, 1920.*

Element of cost.		Totals. Unit.	Totals. Amount.	Per barrel cement. This mo.	Per barrel cement. 1920
Raw material:	No. 1.				0.11
	No. 2.				.15
	Gypsum.				.05
	Total				.31
Labor:	Operating.				.21
	Repair.				.05
	Total				.26
Supplies:	Operating.				.02
	Repair.				.10
	Total				.12
Fuel:	Drying raw material.				.06
	Burning clinker.				.47
	Total				.53
Power, light, and water.	Total				.15
	Direct cost of production:				1.37
Mill overhead:	Superintendence.				.01
	Mill office and stores.				.02
	Laboratory.				.01
	Miscellaneous.				.05
	Total				.09

TABLE 7.—*Statement of monthly costs for December, 1920*—Con

Element of cost.		Totals. Unit.	Totals. Amount.	Per barrel cement. This mo.	Per barrel cement. 1920
Reserves:	Insurance.				0.01
	Taxes.				.01
	Depreciation.				.10
	Total				.12
	Total bin cost:				1.58
Trading:	Inventory First month.				
	Total				
	Inventory end of month.				
	Cost of sales:				
Profit and loss:	Sack cost.				
	Packing and loading.				.08
	Sack handling.				.02
	Cost on board cars:				1.68
	Selling expenses.				.12
	General expenses.				.08
	Financial expenses.				.05
	Total costs:				1.93
	Net operating profit.				
Sales:	For month.				
	Net profit brought down.				
Extraneous income.					
Total net profit	Estimated.				

TABLE 8.—*Balance sheet.*

Assets.			
Cash in banks:			
First National			
Second National		$205.250 00	
Petty cash:			
General office			
Mill office		500 00	$205,750 00
Bills receivable			
Accounts receivable:			
Customers'			
Less reserves			
Advances			200,000 00
Investments			
Inventories:			
Cement		60,000 00	
Stores			
Gypsum		40,000 00	
Explosives		1,750 00	
Coal—kiln		12,500 00	
Coal—steam		4,000 00	118,250 00
Total current assets			524,000 00
Deferred assets:			
Shut-down expenses			
Work in process—			
Raw material		5,000 00	
Clinker		10,000 00	15,000 00
Stores			
Capital assets:			
Bags, cloth—new			
Deferred cost			
Bags, cloth—second-hand			
Bags, paper			180,000 00
Mill buildings		1,317,750 00	
Dwellings			
Less reserves			
Mill machinery		1,302,250 00	
Quarry equipment		175,000 00	2,795,000 00
Less reserves			
Land, Quarry No. 1			
Land, Quarry No. 2			
Less reserve			
Land, mill			125,000 00
			3,639,000 00

TABLE 9.—*Comparative costs per barrel.*

(Capacity of mill, 2,000 barrels per day.)

	1914	1915	1916	1917	1920 (10 months to Nov. 1).
Number of barrels cement manufactured	401,727	336,918¼	366,376¼	218,814¾	248,152¾
Materials:					
Raw material No. 1	0.05114	0.04670	0.05257	0.06566	0.10993
Raw material No. 2	.05328	.05313	.05482	.07167	.20582
Unground coal	.11034	.10955	.14389	.24098	.46754
Gypsum	.01440	.01647	.01770	.02366	.03966
Sweepings	.00140	.00218	.00172	.00319	.....
Composition	.....	.00046	.00028	.....	.....
Total	.23056	.22849	.27098	.40516	.82295
Labor:					
Operating	.06397	.05467	.06970	.09814	.20566
Repairs and maintenance	.01181	.01526	.01720	.03108	.04198
Total	.07578	.06993	.08690	.12922	.24764
Supplies:					
Operating	.....	.....	.....	.....	.01449
Repairs and maintenance	.04561	.03959	.04294	.05059	.09745
Tools	.00007	.00010	.00013	.00016	.00084
Oil and waste	.00351	.00327	.00353	.00462	.00772
Fuel	.00850	.01146	.01357	.02184	.06225
Total	.05769	.05442	.06017	.07721	.18275
Expenses:					
Power, light, and water	.07194	.07070	.09310	.14117	.26203
Laboratory	.00397	.00420	.00383	.00477	.00858
Shops	.00256	.00353	.00446	.00459	.00220
Teaming	.00053	.00081	.00089	.00134	.00149
Mill office	.01195	.01349	.01268	.02026	.01539
Boarding house	.00075	.00034	.00090	.00043	.00317
Welfare work	.....	.....	.....	.....	.....
Total	.09170	.09307	.11586	.17256	.29286

TABLE 9.—*Comparative costs per barrel*—Continued.

	1914	1915	1916	1917	1920 (10 months to Nov. 1).
Provisions for—					
Depreciation and obsolescence	0.10000	0.10000	0.09999	0.10000	0.10000
Insurance	.00861	.00919	.01264	.01626	.00778
Taxes	.01356	.01479	.01314	.01485	.01002
Contingencies	.01270	.00714	.00891	.....	.00364
Packing and loading	.03500	.03088	.03969	.04923	.08154
Sack handling	.00909	.00623	.00764	.01234	.01495
Total	.17896	.16823	.18201	.19268	.21793
Total mill cost	.63469	.61414	.71592	.97683	1.76413

NOTE.—None manufactured in 1918 and 1919.

TABLE 10.—*Comparative costs per barrel.*

(Capacity of mill, 3,900 barrels per day.)

	1914	1915	1916	1917	1918	1919	1920 (10 months to Nov. 1).
Number of barrels of cement manufactured	355,260	491,239¾	596,081	634,252	705,099½	847,709¾	646,931¾
Materials:							
Raw material No. 1	0.05300	0.05026	0.05756	0.07579	0.08053	0.08074	0.11441
Raw material No. 2	.03023	.04242	.05462	.03882	.05362	.06014	.09159
Unground coal	.10599	.10418	.13594	.21843	.24705	.20224	.38034
Gypsum	.01647	.01474	.01681	.02131	.02672	.03069	.04187
Sweepings	.....	.....	.....	.00032	.00131	.00096	.00194
Total	.20569	.21160	.26493	.35467	.40923	.37477	.63015
Labor:							
Operating	.04467	.04170	.04456	.05990	.07352	.07675	.10885
Repairs and maintenance	.01686	.01568	.01577	.02110	.02066	.02341	.02864
Total	.06153	.05738	.06033	.08100	.09418	.10016	.13749
Supplies:							
Operating	.....	.....	.....	.....	.....	.....	.00996
Repairs and maintenance	.04752	.04553	.04298	.04532	.06005	.06186	.07290
Tools	.00008	.00013	.00048	.00036	.00030	.00028	.00023
Oils and waste	.00448	.00456	.00437	.00471	.00672	.00821	.00798
Fuel	.00767	.00780	.00865	.01388	.01399	.01389	.03588
Total	.05975	.05802	.05648	.06427	.08106	.08424	.12695
Expenses:							
Power, light, and water	.09533	.06623	.07390	.10696	.16358	.13091	.16242
Laboratory	.00354	.00313	.00312	.00322	.00585	.00899	.01094
Shops	.00290	.00225	.00301	.00345	.00642	.00380	.00315
Teaming	.00018	.00002	.00029	.00013	.00064	.00024	.00001
Mill office	.00913	.00990	.01020	.01494	.01959	.02037	.01987
Boarding house	.00052	.00022	.00093	.00072	.....	.....	.....
Welfare work	.....	.....	.....	.....	.....	.....	.00429
Total	.11160	.08175	.09145	.12942	.19608	.16431	.20068
Provisions for—							
Depreciation and obsolescence	.10000	.10000	.10000	.10000	.10000	.10000	.10000
Insurance	.00681	.00652	.00945	.01357	.01693	.01419	.01230
Taxes	.01094	.01047	.00969	.01132	.01691	.01652	.01469
Contingencies	.01316	.01344	.00814	.01565	.01349	.01176	.00243
Packing and loading	.03500	.02731	.03157	.03821	.04274	.04952	.07664
Sack handling	.00901	.00455	.00587	.00425	.00957	.01239	.01376
Total	.17492	.16229	.16472	.18300	.19964	.20438	.21982
Total mill cost	.61349	.57104	.63791	.81236	.98019	.92786	1.31509

TABLE 11.—*Summary of mill cost and overhead.*

	1914	1915	1916	1917	1918	1919	1920 (10 months).
Barrels manufactured	756,987	828,158	962,457¼	853,066¾	705,099½	847,709¾	895,084
Barrels sold (including foreign)	839,584½	852,099	964,286	933,423	706,837½	893,969½	906,655
Mill cost	0.62474	0.58857	0.66760	0.86627	0.98019	0.92786	1.43958
Overhead (including selling, administration, financial)	.18253	.17543	.19338	.20225	.22805	.29129	.20733
Total cost	.80727	.76400	.86098	1.06852	1.20824	1.21915	1.64691
Average selling price received	.05965	.75140	.96668	1.23709	1.36995	1.54509	1.75422

During the sellers' market of the past few years there have been many obstacles placed in the path of the manufacturing executive, and it remains to be seen what the developments will be in the buyers' market, which is now seemingly at its commencement.

In conclusion, the writer has endeavored to treat the subject from an impartial viewpoint. Using public moneys to develop industrial enterprises which of necessity will compete with private corporations is a hazardous venture. It should be undertaken only under the most extreme provocation and when conferences, investigations, and possibly regulatory measures have failed.

DISCUSSION OF MR. HILTS'S PAPER.

R. J. Windrow, State highway engineer, Texas: As a result of a resolution passed by the Texas Legislature, we have been investigating the proposition as to whether it will be advantageous for the State to own and operate a cement plant of its own. The facts which we have uncovered in our investigation thus far lead us to conclusions similar to those which have been drawn in the paper under discussion.

There were two fundamental principles that we had in mind at the outset of our investigation. The first was that the cement industry which we were considering entering is only incidental to the main business in which we are engaged. Our main business is the construction of highways and in that work we need some cement, a large amount or small amount as it may be. Keeping in mind, therefore, that the production of cement is essentially a side line, we have asked ourselves two questions—first, is our demand for cement large and constant enough to enable us to make a profit on this side line, as you might call it; second, is the present source of supply not reliable enough to enable us to proceed with our main business in an efficient way? The other main consideration that we had in mind was the fact, that we consider has been well established, that a Government-owned plant of any kind can not be operated as efficiently as a privately owned plant.

With these considerations in mind, we went to the cement companies and gave them the opportunity of presenting the facts from their standpoint. They threw open their plants and their records to us, and as a result, we have been able to get a little light on the subject. But the further we have gone into the investigation the more nearly have we come to the conclusion that it is a proposition we do not care to recommend to the State. Certainly, if we can depend upon the cement companies enlarging their plants sufficiently to take care of our future needs, we do not care to enter into the cement business. One of the principal deterring reasons is that we do not know whether a single State plant would improve matters. Our territory is so large that there is no doubt that we could use the entire output of a plant with a daily capacity of 2,000 barrels, but, of course, that plant would have to be located at one point. We could not compete with the five privately owned plants that are scattered throughout Texas, due to the freight rate and transportation problem. Therefore, the territory in which we could economically use cement from our State-owned plant would be restricted, and we would either have to take care of only part of our demand from the State-owned plant or would have to establish several plants in order to meet the competition. Therefore, instead of the investment being two or two and one-half million dollars, it would be several times that. We would be entering into a very large industry and we do not believe it advisable to develop a side line to that extent.

Difficulties Experienced by the States in the Matter of Rail Transportation.

S. E. BRADT, Superintendent of Highways, Illinois.

THE rail transportation difficulties encountered in Illinois have not differed materially from those encountered in the other States of the Mississippi Valley, and probably all of the States attempting to carry on a large program of highway construction are meeting with similar troubles.

Shortly after the signing of the armistice in November, 1918, the States were urged by the Department of Agriculture to proceed as fast as possible with the construction of roads with money made available from the Federal appropriation. This was urged because of the possibility of idle labor due to the slow absorption of the released army into ordinary pursuits and because of the releasing of the thousands of people employed in the war industries.

Illinois, acting in harmony with this suggestion, proceeded to make preparations, and awarded contracts for about 570 miles of hard-surfaced roads, costing some $32,000 per mile. It was hoped that at least 400 miles would be completed during the season of 1919. We were at the beginning of a new era of road building in Illinois; hence, many contractors were obliged to buy complete equipments, and all of them, at least, some additional equipment. The manufacturers, instead of

being able to furnish them equipment within 30 days, as promised, required from 60 to 90 days to make delivery. This prevented an early start on the part of the contractors. As soon as the contractors were ready for the delivery of material, a shortage of open-top cars developed. This was followed by the shopmen's strike, which crippled the motive power of the railroads; and later in the season came the coal strike, in anticipation of which all open-top cars were taken from the building industries and sent to the coal mines. The result was that, instead of 400 miles being completed, we ended the season with 170 miles of finished roads and carried over to the 1920 season approximately 400 miles unfinished.

PROGRAM UPSET BY CAR SITUATION.

The bond-issue law called for construction at the rate of approximately 1,000 miles per year. Accordingly, we made tentative plans for putting that mileage under contract for 1920 construction. Because of the handicap placed upon the 1919 construction work through the inability of the railroads to furnish sufficient equipment for the transportation of material, we visited the officials of the Railroad Administration with a view to ascertaining the possibility of obtaining cars if we undertook a program involving the addition of 1,000 miles of roads. We explained to them that the building of 1,000 miles of roads meant the delivery of 1,000 cars of material a day. Figuring that each car would consume eight days in making the round trip, our requirements would be at least 8,000 cars continuously during the highway construction season. We were advised that in the spring of each year, from March 1 to July 1, there was ordinarily a supply of a quarter of a million or more of idle cars, and that if we could arrange to have a large portion of our material delivered before July they would be able to take care of our requirements.

In accordance with these suggestions from the Railroad Administration, we arranged with our contractors for the storage of materials. They began to call for cars in February and March, but instead of the required number of cars being available it developed that the year 1920 was unlike any of the preceding years and that there was no surplus of idle cars available. As a result, few contractors were able to get a supply of material stored in advance of construction.

As soon as we asked for bids on new construction it also developed that, owing to the uncertainty of transportation, the increased price of labor and material, and the uncertainty of the general situation, our bids, instead of averaging $32,000, as in 1919, averaged $44,000 per mile. With all these things facing the department, it was decided to reject bids and to award contracts for only about 50 miles instead of the amount originally planned, putting all of our effort into the completion of the 450 miles. To this end Gov. Lowden called a conference of the producers of materials and the railroad presidents, all of whom pledged the fullest possible measure of cooperation in carrying out the plans of the department, and it is but fair to say that in our opinion this pledge was fulfilled to the best of their ability.

The contractors who were working in 1919 closed the season with approximately 100 paving machines on the ground, ready to start the 1920 construction work as soon as materials were available and weather conditions suitable. At no time during the entire season, however, were there more than 53 of the 100 machines in operation, and the average for the season was much less than 53. This situation was due almost entirely to insufficient transportation facilities.

ORDERS CAUSE DIFFICULTIES.

The first interference with our work came in the shape of a switchmen's strike, which caused a congestion of freight cars in practically all of the centers of population in our vicinity and prevented their movement for a number of weeks. However, the most serious difficulty experienced has been the various orders issued from Washington by the car-service commission and the Interstate Commerce Commission. Early in June the car-service commission issued an order requiring that coal mines should be given 50 per cent of their rated car requirements and that plants producing other commodities requiring open-top equipment should be restricted to the use of the remainder of the cars, whatever that might be, but not exceeding, to any one plant, more than enough cars to transport 50 per cent of its output. This immediately reduced the shipments of road materials. This order was followed on June 21 by another order, issued by the Interstate Commerce Commission, providing that open-top cars could be used for hauling material other than coal only when returning to the mines. This order was to be in force only 30 days, but was renewed at the end of each 30-day period and remained in force throughout the construction season. Perhaps 50 per cent of our contractors were doing work in localities that permitted all of the material for their work to be handled in accordance with this order without interruption. The other 50 per cent, however, were getting material in localities requiring a "back haul," which was in violation of the ruling. Within a short time after the order went into effect material coming to them was stopped. We appealed to the Interstate Commerce Commission and a hearing was called early in July. The result of this hearing was the issuing of special permits, but only after a delay of several weeks. These permits were granted only for the hauling of material for the completion of old contracts where work was being done on sections of important roads. Our work

was all being carried on upon the main highways of the State; accordingly, by the middle of August we had secured permits for most of those contractors requiring a "back haul" for their material. These permits were generally put into effect by the railroads, but occasionally some road would get an order from Washington to deliver a certain number of cars to some special plant for a specific coal loading, which, of course, interfered with work in that vicinity.

In September an order was issued from Washington suspending all permits for a period of 10 days. This again suspended the movement of material for road work. At the expiration of the 10-day period road work was resumed, but early in October another order came from the Interstate Commerce Commission canceling all permits and requiring that additional evidence be submitted before those permits would be renewed. We succeeded in securing the renewal of not more than five of the old permits. Because of this interference, mainly through the two commissions mentioned, we have been able to complete only a little more than 300 of the 450 miles. In order to do this, much of the time of the officials of the department, as well as all of the time of experts employed for that purpose, has been given to the securing of car equipment and connecting it up with the producers of road materials so as to keep contractors supplied with as large an amount of material as possible.

TRANSPORTATION LIMITING FACTOR.

During the seasons of 1919 and 1920 we have built 500 miles of high-class hard-surfaced roads. The same effort put forth under ordinary conditions and without the hindrances herein enumerated would easily have completed 1,000 miles of the same class of roads, which would have proved reasonably satisfactory to our people.

As a result of this situation, it will be seen that the people of Illinois have suffered great inconvenience because of the inability of the contractors to finish their work promptly, and that the contractors have been subject to excessive losses because of insufficient transportation facilities.

It will also be seen that the producers of material, through their failure to secure cars for a normal output, will be subject to losses, due to the fact that the overhead expenses remain practically the same under a reduced output as under a normal output.

All of these losses will in a large measure come back to the people in the added cost of construction of future work.

We can not remedy the past; our problem lies in the future.

We have the contractors.

The contractors have the equipment.

Labor has been in fairly good supply this year and the indications are that it will be more plentiful next year.

The money is available.

Materials are in ample supply at their source.

As nearly as we can judge, the one principal limiting factor in 1921 will be transportation. In so far as the railroads are able to solve this problem of transportation by the purchase of added railroad equipment, by the repair of present equipment, by increasing the number of car-miles per day so as to carry on our work without governmental interference, just so far the improvement of the highways of Illinois and other States in the Mississippi Valley will be carried on in an increasing portion. This is the important problem.

DISCUSSION OF MR. BRADT'S PAPER.

M. W. WATSON, State Highway Engineer, Kansas.

The highway programs of Kansas and her neighboring States suffered far more by the inefficiency of rail transportation during the past season than from all other causes combined. Of course, we had some other troubles, such as inefficiency of labor, shortage of cement, and bad weather, but these troubles were Lilliputian in comparison with those arising out of the rail situation. Although labor was inefficient, there seemed to be plenty of help available. What we lacked in quality we could make up in quantity or the substitution of machinery. The cement shortage seemed to be traceable to the unsatisfactory rail situation. The hesitancy of cement companies to contract for definite deliveries was due to uncertainty. While we had more wet weather than during ordinary seasons, there were many ideal days for road building that were lost on account of the nonarrival of materials.

During 1919 and 1920 we placed under contract in Kansas approximately 358 miles of Federal-aid road work, 77 miles of earth roadway and culverts preliminary to surfacing, 69 miles of gravel, 30 miles of macadam, 126 miles of concrete, and 55 miles of brick. Of this amount we had completed on November 9 approximately 13 miles of earth, 24 of gravel, 5 of macadam, 31 of concrete, and 23 of brick. Under normal conditions practically the entire mileage should have been completed at the close of the construction season.

LOCAL CONDITIONS KANSAS FACTOR.

The situation in our State is aggravated by the location of our hard-stone supply so close to our coal-mining territory. There is a decided lack of a well-distributed supply of stone having sufficient hardness to be used in the construction of concrete roads. Our

main deposit of material of a satisfactory character is the flint spalls and chats from the zinc and lead mines of the Joplin district in southeastern Kansas, southwestern Missouri, and northeastern Oklahoma. This deposit not only supplies a large part of Kansas but also southwest Missouri, a considerable part of Oklahoma, and a portion of Arkansas. The coal fields which supply a large part of Kansas, Missouri, and Oklahoma are also located in southeastern Kansas and southwestern Missouri, only a few miles distant from the flint regions. The utilization of empty coal cars for the transportation of the flint is impossible, because the road projects are located in the same direction from the coal mines as the markets for coal.

The bulk of our sand comes from the Kansas and Arkansas rivers and in only a few instances are the plants so located as to utilize returning empties from coal shipments.

The producers of materials demanding open-top equipment for their shipments are now discovering that they have overlooked a valuable piece of propaganda which has been of decided service to the coal interests during the past construction season. The general public has been trained to term all cars of the open-top variety as coal cars until even the Interstate Commerce Commission seems to think that there is only one use to which such cars can be put. This fact, together with the apparently well-organized lobby of the coal interests, has been the means of securing embargoes and priority rulings until we become dizzy if we attempt to trace these orders around the circle they have been following. Congress would render a great service to industry in general and especially to the construction activities if it would legislate out of use in the commercial world the three words that have spelled a large part of our grief, "embargo, priority, and permit." It is true that in the end we were obliged to resort to the permit system for the highway shipments, but only to counteract the methods other interests were employing and after all other measures had failed. Such practices during war time may be necessary but after the close of hostilities they should be placed in the discard. They can lead only to one end, that is, preferential treatment for the industry with the best organized lobby.

COMMISSIONER CLARK'S SUGGESTION.

Chairman Clark, of the Interstate Commerce Commission, has recommended to the Senate Interstate Commerce Committee that a differential freight rate be granted so as to distribute the coal shipments throughout the year. The following is a quotation of his statement, in part, taken from Railway Age, March 26, 1920:

Such legislation would obviate very largely the pressing necessity for more coal cars. The present supply of coal cars, while totally insufficient to handle the fall and winter rush under existing conditions, would be fairly adequate to carry all the coal desired by consumers if this equipment could be kept moving with greater regularity throughout the year, as would be the case if the advantage of lower summer and spring freight rates could be held out to induce consumers to receive coal shipments in advance of their winter needs. Under the present system thousands of coal cars lie idle during the spring and summer, while the whole available supply of coal cars is entirely insufficient to handle the fall and winter emergency.

The acquisition of more coal cars does not afford a practicable and complete remedy for existing difficulties. Under the transportation act, recently approved, the Interstate Commerce Commission is given the power to require carriers to provide themselves with sufficient cars. But most of the railroads have neither the money nor the credit with which to buy a supply of coal cars adequate for current needs under the present system of large seasonal shipments, so it would be useless for the commission to order them to purchase this equipment. On the other hand, most of the railroads which have enough money or credit to finance such purchases already possess an adequate number of coal cars to care for the needs of their own patrons, and they could not reasonably be required by the commission to purchase additional cars to take care of the traffic of other lines.

Apparently Chairman Clark does not realize that there are other industries which need cars as well as the coal industry. The concentration of coal shipments has been the solution of our problem in the past. Coal shipments have been greatest when the needs for fuel were greatest; that is, during the winter months. These cars were then available for building materials during the summer months, which is the only time when building operations can be carried on satisfactorily. The clever coal propaganda has done nothing more than secure the increase of price desired by the operators. Part of the time this season when the open-top cars were withheld from stone shipments our mines were idle. It would seem the policy of the Interstate Commerce Commission to reduce the scope of the Nation's activities to the size of our present rail transportation rather than to utilize what we now have to develop our other avenues of transportation.

The other classes of equipment were also scarce, at least for our use. The grain producers of Kansas were unable to secure relief. Grain was piled high in the open in many places throughout the States while the elevators were filled to capacity. When orders were given to ship empties to the West for the relief of this situation we observed that the empty cars were allowed to stand idle in the yards for many days, while our most urgent appeals were of no avail to secure them for loading westward, even though they were to pass empty through points where the materials were needed. Refrigerator and cattle cars hold the same status as box cars in our shipping arrangement. They go eastward through the State when loaded, and empty westward. Long trains of empties passed by the cement and brick plants, but were not available for use.

DELAYS IN MOVING CARS.

Through the cooperation of the State industrial court and our local engineers it was found that empty cars would stand in the railroad yards throughout the State for days and even weeks at a time. In some instances they were moved from one end of the yards to the other and then in a few days returned. When the railroad officials discovered that our men were checking their yards they ordered them to stay out and threatened arrest for trespassing. Why?

The most curious part of the entire procedure is the speed with which conditions changed when the higher rate went into effect and the Government guaranty was removed. It seems a general theory of public utilities operation that when a higher rate is requested the service becomes almost unbearable until the public is willing to try anything for relief. Gas service becomes decidedly improved after the rate is increased, and central will give you the number requested at least a part of the time after the telephone rate is advanced. Records show that the larger railroad lines operating in Kansas and in fact in other States as well are not utilizing their present equipment to its fullest capacity. One of our roads gets from 54 to 86 car-miles per car day out of its freight cars, while another gets from 17 to 22 or not quite as far in a day as the average team will travel.

The investigations of our industrial court brought out that many unaccountable delays occurred at terminals. They followed closely 412 open-top cars used in coal shipment from the mines to destination and return. Of these cars 171 were loaded with company coal. The average number of days consumed in the assembling yards was 4.25. Company coal required an average of 4.29 days to travel to destination; commercial coal, 3.54 days. The total car-days consumed at destination in unloading and delivery to connecting lines amounted to 1,773 for company coal and 760 for commercial coal. The average travel per car-day for company coal was 6.3 miles and for commercial coal 13.4 miles. Of 273 cars unloaded, 4 required 30 days, 11 required 29 days, 4 required 28 days, 9 required 27 days, 10 required 26 days, and 18 required from 13 to 25 days; and the surprising part of the statistics is that the railroad companies seemed to be the ones who were longest in unloading their cars. This does not look as though the grave warnings issued to shippers by the Interstate Commerce Commission were placed in properly addressed envelopes.

Let us hope that conditions will continue to improve, but in the meantime the highway industry, which is the coming industry of the day, should awaken to the necessity of securing adequate recognition from the powers governing the railroad situation and a better understanding with the carriers themselves. Some of our railroads have assumed the policy of fighting highway improvement and seem to look upon the highway, with its improved transportation facilities, as a serious competitor. We know that this country is developing more rapidly than all the methods of transportation, so that the highway program should be aided by the railroads rather than hindered.

If the construction of highways could be worked out so that they would build themselves by allowing the hauling of materials over the newly constructed roads as we go we might be independent of the railroads. But it is not possible in highway work to regulate the places where we are to start as well as might be were it a private enterprise, and in most States we must depend on rail transportation for the success of our highway program.

COMMISSIONER COLEMAN'S VIEWS.

George P. Coleman, State highway commissioner, Virginia: I am sure we have all passed through much the same experiences in our transportation difficulties. A year ago we were told that there would be available 250,000 to 300,000 open-top cars for road-material transportation during the spring months and that it would be advisable for the State highway departments to store all the material possible during those months. I presume that many of the State departments prepared to follow that advice; at any rate, we did make such preparations in Virginia. Then we started looking for cars. We found the cars right in the State of Virginia, but the trouble was to get them loaded and moved. There were thousands of cars standing idle, not for days only but for weeks in some instances, as our records show. Yet in spite of this fact we could not get them. Whose fault it was or why I am not prepared to say. Following that the Interstate Commerce Commission rained down on us priority order after priority order. We came up to Washington seeking relief, but we were practically told by the Interstate Commerce Commission that highway construction was a nonessential. Perhaps it was not put quite so bluntly as that, but at any rate I received the impression that it was considered that highway construction could be held up for an indefinite period. The reason assigned was that New England needed coal. We were glad to let New England have it. Again we were told that the Northwest needed coal. We were glad to let the Northwest have it, because ours is a coal State and we derive our revenues largely from coal. Yet in the face of all this preference given to coal, the result has been very curious so far as Virginia is concerned. We have received and shipped more coal than ever before in the history of the State, and yet to-day there are sections of Virginia that are facing a coal famine.

That leads me to the point which I should like to make, which is that the railroads are unequal to the

task imposed upon them, and that highways are needed to assist them in improving transportation conditions; and we should do our utmost to convince the Interstate Commerce Commission of that fact.

I would change the wording of the subject under discussion and make it, "Transportation difficulties and how we are to overcome them, using our experience of the past year in aiding us to a solution." The past is behind us, and we should now bend our efforts toward the improvement of conditions in the future. It seems to me that the principal lesson to be learned from our past experiences is that we must impress upon the Interstate Commerce Commission the importance of the work which we as highway engineers are doing in this country. We must make it clear to the commission that highway transportation is as essential, in many instances more essential, than rail or water transportation, and that we can give valuable assistance in the efforts which are being made to unravel the transportation tangle.

What the Highway Departments May Expect In Service in 1921 from the Railroads.

A. G. GUTHEIM, Car Service Section, American Railway Association.

THERE is no use trying to plead a clean bill of health for the railroads during the past four years. I have talked before a number of different associations throughout the country on somewhat this same subject—the open-top car situation—and I always get down to the same proposition. You can not handle the bituminous coal business of the United States in production peaks of 13,000,000 tons a week and production valleys of 7,000,000 tons a week and reach a total annual production sufficient to meet the country's requirements and still conduct transportation in anything like an ordinary and normal manner.

What we have done in the past two years and to a lesser extent in the preceding two years on coal production—and I speak now of bituminous coal production—is this: We have tried to get for this country all the coal it needs, utilizing a deficient railroad plant that has not grown to speak of for four years, and we have found ourselves compelled to attempt the job with a production some weeks of 13,000,000 tons, and other weeks pretty close to 7,000,000 tons. And it simply can not be done without disturbing other business.

A year ago I was asked to discuss the transportation outlook for 1920 before several associations concerned in road building. I gave it as my opinion that the railroads should do a pretty good job. The roads went back to their owners on March 1. Progress in March was good and we hoped we would do well thereafter, but the switchmen's strike started on the 7th of April. There were probably never more than 25,000 or 30,000 men out on the switchmen's strike out of perhaps 2,000,000 railroad employees, but they went out at psychological points—at Chicago the first day, Toledo the next, St. Louis the third day, Harrisburg the fourth day, New York the next week. I don't know if the points were picked. I don't claim that they were, but the facts are that the points at which trouble occurred were such that, usually, particular harm was done to coal production.

Now, your road-material problem is tied up inevitably and always with the coal problem. You can not get away from it. You must use the open-top cars. There has been no great increase in the ownership of open-top cars in this country for the past four years. The Railroad Administration in its entire career purchased about 100,000 cars, of which 50,000 were open-top cars. That was nowhere near enough to take up the usual retirements. When the roads went back to their owners, March 1, they had just about as many open-top cars as when the Government took them over January 1, 1918. They had a relatively greater bad-order condition. As the new cars purchased during Federal control were way down, and there was no great increase in ownership during Federal control, it follows that the retirements during that control were nowhere near what they ought to have been. Therefore the roads were returned to their owners with a condition of equipment that was worse by far than it should have been.

COAL PREFERENCE ORDER NECESSARY.

But despite all this, if we had faced a bituminous production of about 10,500,000 tons a week we could, without doubt, have handled the job and supplied the country according to its requirements from week to week, permitted replenishment of stocks, and successfully met the aggregate requirements for the year without unduly affecting other industry. But that problem, for reasons beyond our control, didn't come to us in just that fashion. We did get up to 11,000,000 tons of bituminous production in March, and then in the middle of April we got down below 8,000,000, and there we stayed a while. Finally the situation was presented to the Interstate Commerce Commission with the advice that as long as we were in the troubles we were then facing it would be impossible to take care of the country's coal requirements unless some preference in transportation were given to coal. The railroads made

that recommendation. I personally framed the figures on which it was based, and I am perfectly willing to accept my share of the responsibility.

The Interstate Commerce Commission evidently agreed with us, and they put in their Service Order No. 7, which merely made more stringent our so-called 50 per cent rule. On the strength of that preference by service order of the Interstate Commerce Commission we have obtained a 1920 bituminous production that up to date is in the neighborhood of 525,000,000 tons. When we were before the Interstate Commerce Commission with respect to Service Order No. 7 in early July and the question was asked, "What coal is needed in this country for the current year?" the answer was, "About 535,000,000 to 545,000,000 tons." We will get just about that figure, and mark you, it is only in the last week that any considerable number of mines have reported to the Geological Survey that they have lost working time for want of market, and it was yesterday that I heard for the first time that coal was standing under load on wheels not billed for want of orders. To my mind, that demonstrates conclusively that our judgment as to the coal needed was right.

CONDITIONS WHICH GOVERNED.

Now, that brings us down to this question of "nonessential" work. I have lived in this war period pretty close to "nonessentials." I have heard them dubbed "nonessentials" and then "nonwar"—probably it sounded better. I am willing to admit that road-building work is essential, but I should like to ask you whether you would want road-building work to go on unlimited at the expense of leaving thousands of communities without coal?

Reference has been made to the fact that conditions changed when the rates changed. They did, but the switchman's strike changed about the same time. You may remember that the Railroad Labor Board gave its decision on the wage increase just about a week or two weeks before the Interstate Commerce Commission gave its decision on the rate advance. The decision on the wage increase settled the labor situation, and that is where we began to get some light toward better operation. The decision of the Interstate Commerce Commission followed, and it wasn't that, but the better railroad operation resulting from the stabilizing effect of the wage decision, that gave us better service about the time the increase in freight rates took effect.

With respect now to this spring and early summer surplus of cars which failed to materialize: You can go back to the years previous to 1916 and you will find that every year the surplus of open-top cars was considerable; in fact, there have been cases in past years where roads that were large owners of open-top equipment had to go to the expense of building temporary side tracks on which to store the cars that were routed back to their owners by other lines that did not want to hold them and pay the per diem rental for them. That situation has not obtained since 1915, except in 1919, when the country was living off of the bituminous stocks, which amounted to 63,000,000 tons on Armistice day, and we lived off these stocks to an extent which, coupled with the coal strike, resulted in what you have gone through the past year. If we can obtain bituminous production at anything like a uniform weekly rate, there isn't the slightest doubt that there will be a regular and good volume of open-top car service for road materials. There will not be in the future relatively the same excess of car service over and above coal requirements that there has been in the past unless the railroads again become overequipped to the extent that they were then, and I don't believe that is likely to happen.

THE CAR SITUATION TO-DAY.

Mr. Willard asked me to discuss the car situation as it is at the present time. We are now approaching a stage where we have the coal situation well cared for. With reasonable winter weather and freedom from labor troubles in the mines we ought to get along without any distress this winter. We don't know just how well the stocks are distributed, so we can't tell individual needs. We do know that low-priced purchasers—the railroads and public utilities particularly—have had trouble. The rates they may charge for their service are fixed and regulated and they are not free to pay any price necessary to obtain coal. On this point let me say that I think there is a lack of appreciation among you gentlemen—it was apparent in one of the papers—of the function of the Interstate Commerce Commission in controlling these emergencies. The commission can force transportation for the benefit of some particular commodity to increase production of it, but it has no control, except very indirectly, over the distribution of that commodity to the consumer, and there is no reason why it should have. The Interstate Commerce Commission has no power, except very indirectly, to compel the distribution of coal to a particular consignee. It did it in a degree this past year in the service orders protecting public utilities, the Lake territory, and New England, but all the time that was going on there was uneasiness about the legality of it. It was strong-arm procedure, and a good deal was done to hold off people who were coming to Washington with their lawyers to attack those orders. It was borne in mind that there was a job that had to be finished before winter, and we were going to get away with it if possible.

As to the attitude of the railroads toward highway work, I think there is no one man who can speak for all the railroads. I understand that in the work of your organization you have had the benefit of the association of Mr. M. S. Connors, of the Hocking Valley.

as a railroad representative. He is a man of large experience in this work. He is a man who knows the coal-car game from a to z, knows the particular coal problems as a result of which you have suffered, and he is a good man to keep in touch with on the general problem.

The individual traffic man—and the attitude of the railroads toward highway work would be a traffic rather than a transportation or operating matter—I think the average traffic man will fall into one of two classes: First, the one that figures everything should be done to help along highway work, because there must be in the course of years a development of transportation of short-haul commodities over the highways, leaving the railroads to handle the longer haul and heavier freight, and again to relieve the railroads of a lot of intracity haul, which has been much tabooed the last two years through embargoes; second, the class who would feel that you ought to make short-haul rates to beat motor-truck competition just as years ago they made rates to beat wagon competition. Without attempting to speak for the traffic men I can give my personal views. I think the man in the last class is bound sooner or later to fall because he is butting his head against something that is bound to come, and he might as well recognize that now.

GET MATERIALS ON GROUND EARLY.

As to what the highway association can do to secure better transportation by the railroads, I have some hesitancy in advising you. There has been a good deal of fun made about the advice given during the last couple of years. I don't know what better advice we could have given you or where you could have gone to get better advice. Certainly no one in the railroad would have anticipated a switchmen's strike that would upset affairs as the strike did this past summer. But we don't know now what faces us in 1921, or, indeed, in the next few weeks. I have read some articles on the railroad labor situation recently, and if I wanted to permit myself to do so, I could easily get exceedingly pessimistic, but I choose not to. I think that the thing for you gentlemen to do is to go ahead and figure that you are going to get more and better transportation by far next year than you have had the past two years, but keep in mind that the labor problems are bothering the railroads still, and something may break. Everything you can do in the way of getting materials when transportation is to be had and storing them is what you should do. It costs more, perhaps, but I don't think it costs more than finally throwing up the job when it is half or two-thirds done, perhaps, and going into bankruptcy.

Assuming that we have reasonably normal conditions, assuming that the advances in efficiency the railroads have made this past summer continue, you ought to be able to go right ahead with your work. You may have trouble in places, you will have sections where the requirements for coal will be greater than elsewhere, and where there is a tendency on the part of the individual railroads to lean a bit toward coal where by doing so they can stave off nation-wide agitation like that we have gone through the last year. As to that the Interstate Commerce Commission will be the judge of what must be done. What that commission may have in mind for next year I do not know. But I do know that the representative of the Northwestern States, who lived in Washington for two months this past summer in an endeavor to obtain coal protection for his section, came to me three weeks ago and said he had just seen Commissioner Clark, who said to him, "You tell your people back home to go out and buy coal and then see that it is shipped to them, because we don't intend to go through this next year taking care of what would take care of itself if you had bought your coal." That, I think, goes to the bottom of the coal situation. In the last analysis it usually gets down to price. And Commissioner Aitchison has stated that under the provisions of section 1 of the interstate commerce act price does not make an emergency.

One thing further that you might keep in mind with respect to the situation next year is this. Everything that was done in Washington that helped coal and that injured you didn't come out of a clear sky in Washington. You represent officially the different States of this country. I venture to say there isn't a State east of the Rocky Mountains and north of an Oklahoma-Arkansas line and the Ohio River but has sent its representatives to Washington or has sent urgent communicates pleading for the very preference for coal transportation which you gentlemen were arguing against. That rather indicates to me that a good policy for you to pursue in the future is to line up affairs within your own States. I have seen instances where we had in Washington the highway people and the representatives of the governor of the same State, each claiming the situation at home justified their individual claims. If the coal situation in your various States is not, in your opinion, as serious as it is represented to be in Washington, then it is for you to get together on the matter with the folks at home.

The Relative Service Value of Different Types of Rural Pavements.

A. R. HIRST, State Highway Engineer of Wisconsin.

THE term "relative service value" is open to various interpretations. It might be held to cover only the potential power of a pavement to bear traffic of various amounts regardless of cost or economics, or it might be held to include the two latter factors. The author prefers to include the latter.

Among the characteristics usually listed as important in determining the service value of pavements are the following:

Freedom from dust.
Appearance.
Character of foothold.
Ability to clean.
Freedom from sanitary objection.
Character as regards noise.
Freedom from slipperiness.
Low tractive resistance.

Almost without exception, the characteristics cited above are among the least important of the matters to be considered in determining the service of rural pavements. Some, or all of these factors, are worthy of consideration in specific cases, but it has been our experience that one or all of them combined has had no important bearing upon 10 per cent of the decisions reached in actual practice. They have a much larger value in city and village pavements than in rural highway construction.

The predominant factor in determining the relative service value of pavements is whether or not they serve the traffic effectively and cheaply. It may be stated as a truism that given effective construction and proper width almost any one of a dozen different pavements will give good service. The question to be determined by the highway engineer is whether they have or will give good service cheaply.

TRAFFIC THE FIRST FACTOR.

Highway traffic is, of course, the first factor to be seriously considered in connection with pavement economics. Traffic is the thing which makes highway surfacings worth while and the thing which wears them out. Its amount and its characteristics are important and should always be taken into account.

We are going to shock a good many of our more theoretical brethren by saying that a preliminary traffic census is absolutely valueless in helping to determine the type of surfacing to be used. An inspection of the location of a road on the map, a knowledge of its relation to other roads and to the general highway system, and to business centers, together with a consideration of the business tributary to it and probably to be tributary to it, will tell a highway engineer who knows his business whether the construction in question should be first, second, or third class. The traffic on a road last year or last month has absolutely no value in this connection, because when a highway becomes a part of a superior highway system or when one highway is paved with a surface superior to that on the adjacent and competing highways, traffic is so concentrated on that highway that what has been is no indication of what will be. Neither can anyone foresee from the fact that 100 automobiles a day passed over a highway on the 19th of June last how many vehicles will pass over it on the 19th of June, 1932.

Any assumption of what traffic will be is merely an assumption, and the presence on a certain past day of 100 automobiles, 10 trucks, 8 farmers or their wives in single buggies, and 3 babies in their perambulators has really no bearing on the future situation.

Traffic counts have value only as serving to give accurate information as to the constantly occurring changes in traffic conditions and in determining the relative cost of service per unit given by various pavements. The unit cost per ton of carrying traffic is the important consideration and, unfortunately, we have little or no information on this point.

The fact that this type of pavement was maintained for so much per annum and this type for so much per annum means little, unless we know the amount and weight of the traffic served and that it was served adequately.

Even then the information would not be conclusive, because the pavement which gave this unit cost under the prevailing soil and climatic conditions might give an entirely different unit cost under different soil and climatic conditions. A light, sandy gravel on a clay soil will give excellent service value if the rainfall is heavy and well distributed, while it would be totally unsatisfactory under the same traffic in an arid region or in one subjected to only seasonal rains. Similar instances could be cited ad infinitum.

We have been too prone to assume from the results of experience with a limited number of stretches of a certain type of pavement, built and maintained under certain conditions, that the same results will ensue from the use of the same pavement wherever it may be built. This is not the case. Climatic, soil, and rainfall conditions must be considered as well as traffic and general performance.

WEIGHT OF TRAFFIC.

Among the important circumstances affecting the service of pavements is the weight of the traffic which the pavement bears.

American highway engineers have been condemned by the unthinking for having built roads which have not stood up under the intense motor truck traffic of recent years. It would be just as sensible to condemn a railroad engineering department for the failure of railroad bridges under engines weighing 200 tons when the bridges were designed for engines weighing 20 tons. Before new and heavier loads are allowed on any length of railroad, all parts of the construction are examined and, if necessary, strengthened or rebuilt before the new traffic is allowed to pass over them. There has been nothing of this in highway practice. Loads almost without limit have been placed upon highways designed for conditions existing and anticipated a decade ago, and condemnation has resulted when the inevitable failure of the road structure ensued.

It would seem that it would be clear to even the feeblest minded that it is not going to be possible for the designers of vehicles using highways to turn loose upon highways any behemoth their ingenuity may design at any time they feel like doing so. It isn't possible to reconstruct the highway system of America every few months, or even every few years.

It is imperative that the several States adopt uniform standards for the loads to be borne by roads of the different classes of importance. It is going to be difficult to do this, because when a motor vehicle is once started toward its destination its operator will wish it to carry its full load for the whole trip, but it seems inevitable that we must classify highways as to the allowable loads upon them and that traffic on highways must be made to conform to these loads.

It is undoubtedly going to be possible ultimately for the States to finance the construction of roads between their congested centers and on certain through highways, which will carry, every day in the year, loads of 12 or 15 tons or, if the economics of transportation really justify it, even more. But it is just as certainly going to be impossible for the States to finance the construction of any great percentage of their roads so that they will stand such loads every day in the year, and I believe that on the secondary roads and roads of the lower classes much lower load limits must be insisted upon, especially at certain seasons.

The importance of this matter upon the design of pavements and upon the service of the several types can not be overestimated.

CONTINUOUS SERVICEABILITY.

One of the intangible factors in the service value of types of pavement is the factor of continuous serviceability. It goes without saying that given two pavements of equal annual cost, and given one which is out of service for several days each year and probably for two or three months at several times during the assumed pavement life, while the other one allows the passage of traffic during its life with practically no inconvenience and no detouring, the choice would immediately fall upon the one which gives the superior serviceability. Furthermore, if the maintenance of one type demands, annually or semiannually or periodically, the application of materials that prevent the accommodation of traffic during their application or, if they do not completely bar it, that subjects the traffic to possibility of accident from slipperiness and to defacement of vehicles and clothes, then that type is seriously impaired in service value.

I hope I may be permitted to say at this point that one of the strikingly characteristic things about American highway practice has been the almost total disregard for the comfort, convenience, and economy of the traveling public during construction, maintenance, and reconstruction. A "public-be-damned" policy has been quite generally practiced. The traveling public has been considered as an interloper, with no possible business save to pay the bills. The traveler has been estopped from passing through main roads without any option of détours being offered him. He has been not stopped by barriers and has been encouraged to go upon construction and maintenance work which has impaired and defaced his tires, his car, or other vehicle, and his clothes to the extent of hundreds of thousands and, possibly, millions of dollars. Even where detoured he has been only in very few cases properly guided along the whole length of the detour, and even where the detour has been marked, almost without exception it has not been maintained. At best, given a closed road, a well-marked and well-maintained detour (a combination which has been exceedingly rare in American highway practice) the economic loss to the traveling public has been tremendous.

For example: A road carrying a traffic of a thousand vehicles a day is closed for a length of 5 miles, due to construction or reconstruction, for a period of four months, the detour being 8 miles in length, an increase in distance of 3 miles. One hundred and twenty days by 1,000 vehicles by 3 miles gives a total traffic loss of 360,000 miles, which at 12 cents a mile is $43,200, which figure may well have a material bearing upon the type of pavement which one should select. Similarly derived figures will illustrate the importance of speed in construction and reconstruction and demonstrate that it is usually worth paying for.

RELATIVE COST OF SERVICE.

We have been too prone to select types of pavement on the "say so" of others without very careful consideration of the matter of cost. The minute we com-

mence to discuss the relative cost of pavements we are thrown into the field of economic discussion, or rather the ocean of economic discussion, at a point far beyond our depths.

We are immediately brought into contact with the question, "Should an engineer in weighing the merits of two or more types of pavement consider the factor of interest on the original investment?" Many good authorities say "Yes"; many good authorities say "No." I do not pretend to be good authority, but I am sure that the answer is "Yes." The assumption that public money when once spent is gone, and that the public should demand no return upon its investment, sounds to me like the merest bunk. The statement that the value of the pavement in increased comfort, convenience, saving in hauling, saving in gasoline, tires, etc., far offsets the interest on the investment sounds very nice; but what is one going to do about it when one is considering two types of pavement, both of which do all of these things but the costs of which are very dissimilar?

In addition to this little difficulty with the basic economics of the situation, we have the further trouble that in comparing the unit annual cost of various pavements we must make assumptions as to the lives of pavements, and we have little or no information on which to base these assumptions.

It might be of some value to cite the factors entering into an economic comparison and to show just how far one can get in his figuring:

(1) First cost of the pavement: This is readily determinable within the limits of estimating and causes no trouble.

(2) Interest charge on the pavement investment: This charge should be compounded annually and is, of course, readily determinable.

(3) Annual cost of maintenance of the pavement: By maintenance we mean the keeping of the same kind of surface with which we started out; that is, the patching, repairs, and maintenance necessary to preserve it without reconstruction. The cost of this work can only be guessed because no one can predict with more than a moderate degree of assurance what the cost of the material and labor entering into these repairs will be next year or in succeeding years. Furthermore, no one can guess what unexpected development of traffic may entirely upset the conditions under which the surface exists. Therefore, any estimate of the cost of maintenance per year, or for each year, is a guess.

(4) Interest on the maintenance cost: This interest should be added to the cost of the pavement and should be compounded annually.

(5) Life of the pavement before total reconstruction is necessary: Again we are in the field of theory, because the life of the pavement depends upon the traffic which it will carry through a series of years, which we can only guess at. Futhermore, on many of the pavements which are now being widely used, not enough information is available to determine what the life may be, and even on some of the older types of pavement, built under presumably standard and foolproof specifications, a variation of life of several hundred per cent has been noted.

(6) The summation of items 1, 2, 3, and 4, divided by the number of years of expected life of the pavement, gives the annual cost to the public of the pavement as far as the mere outlay of money is concerned.

Before the division by the number of years of expected life is made, however, there should be subtracted from the total cost the value of the old pavement for use in the new pavement. Here, again, we are in the realm of guesswork. Assuming that a certain type of pavement can be preserved for 20 years and will then need resurfacing or replacement by another type, we are making a grave assumption if we attach any material value to the base, because the change in traffic on rural highways is so rapid that it is very hard for one to say that the alignment or grade or culverts or structures that we are building to-day or the widths that we are using to-day will be of any great value to our successors 20 years from now. On less important roads it is probable that structures to-day being built will have a very good value as a part of the structures which will replace them. But on roads of the first class there is grave doubt as to whether or not any of the surfacing will be of value to the kind of pavement that will be placed 20 years from now. However, a guess can be made considering all the factors surrounding the situation, and, as stated above, the sum so determined should be subtracted from the total cost in order to arrive at the annual cost.

At the end of this series of guesses and assumptions upon assumptions, one will have some basis—better than no basis—for comparing the annual cost of the types under consideration.

WIDTH AS A FACTOR IN PAVEMENT SERVICE.

We highway engineers in designing pavements have been open to the same criticism that is being made against those who are seeking to concentrate the major portion of the travel on a very minor portion of all public highways. That is, we have been designing pavements too narrow, and have multiplied our troubles of maintenance by confining traffic to one or two very restricted lines.

The conduct of all pavements, especially of the so-called inferior pavements, such as water-bound macadams, gravels, and the lesser nonrigid types, is good or bad in almost absolutely direct proportion as to whether they have been built wide or narrow. We have had a great deal of discussion of the importance of drainage on highways, and I am not minimizing the importance of drainage when I state that I am convinced that many of the faults of the lesser types of surfacing of which we are complaining are due to the fact that we have concentrated traffic upon too small units of area, and that a better distribution of traffic

will do away with much of the trouble with these types, probably a larger share than will superrefinement in the treatment of the drainage.

I believe that the superiority under traffic of the macadam highways in England and France has been due in part to superior construction, in part to the age of these highways, in part to lesser traffic, in part to the climate, but more largely to the greater widths used in these countries and the consequent better distribution of traffic.

I am not going to develop this thought in detail, but I believe that highway engineers will find that if they will design the so-called nonrigid roads, that is, all roads without concrete bases, wider and flatter, that very much of the trouble incident to the present use of these structures will be avoided.

We have been too prone to compare rigid pavements of a certain width with nonrigid pavements of the same width, rather than comparing rigid pavements of the same cost (I mean total annual cost per mile) with nonrigid pavements of the same cost.

Concrete or other rigid surface laid on what is supposed to be a two-track road built 14, 15, or even 16 feet wide on a main traveled highway has its service value gravely reduced by its inadequate width because it breeds disastrous accidents and causes worry at all times. The shoulder maintenance is also a constant source of worry and grave expense if traffic is at all heavy. Furthermore, the absolute concentration of traffic and the crowding to the extreme edges brought about by such widths reduce the effective life of the pavement very materially. It is the opinion of the writer that even the rigid types of pavement must provide for a moderate distribution of traffic if they are to hold. The minimum two-track highway is 18 feet, and 20 is better on principal highways. If municipalities can not finance these widths they had better build part of their lengths of a cheaper type, pending the securing of more money, building what they now build of proper widths.

Plastic or viscous surfaces of all kinds must have width to allow for traffic distribution, especially if built in a climate of large total variation in temperature. On these types, especially, traffic must be distributed so as to heal its own marks and not deepen them in heated periods.

On primary highways, unless convenient detours are available, all pavements which from their nature require frequent surface attention embarrassing to traffic, should be constructed wide enough so that they can be maintained and repaired one-half at a time.

DESIGN AND SERVICE VALUE.

The service value of any kind of pavement depends largely upon proper design. It is not only necessary that the pavement be properly drained, that it be built of the proper depth and width, but the materials in it must be properly sized and prepared.

For instance, a gravel road built of uncrushed and unscreened gravel, varying in size from sand to cobblestones as large as one's head, has practically no service value to-day, because it is impossible to maintain such a road so as to give satisfactory service to traffic. On the other hand, a road built of the same width and depth and of the same gravel properly crushed and sized may well give most economical service. We in Wisconsin have reached the point where we don't want any gravel within 4 inches of the surface larger than 1 inch, and we prefer it if there is no gravel in the whole structure larger than 1 inch—the smaller the better, our experience indicates.

The service value of any highway may be seriously impaired by the use of sharp and dangerous curves, poor alignment, narrow bridges and culverts, heavy grades, and unnecessary lengths. A well-laid-out highway of inferior surface will many times give better service value than a carelessly located highway built with the best surface. Expressed in terms of real service value, type means little unless the selection of a proper type is supplemented by proper design and proper layout.

MAINTENANCE AS A SERVICE FACTOR.

I believe that maintenance is the keystone of the entire structure of pavement service. Proper selection, design, layout, performance of construction, must be followed immediately by intensive maintenance if the potential service value of a pavement is to be secured. Any discussion of the service value of any type of pavement has no basis unless the assumption is made that good maintenance protects the pavement and gives it a chance to serve. Types seemingly unsuited for the traffic may well, when properly maintained, give better service than a much more suitable surface left to care for itself. We are all familiar with the necessity of proper maintenance, however, and with this slight mention I will leave it.

TRAFFIC DISTRIBUTION ON SEVERAL ROADS.

I am going to interject just a word or two on this important topic. We are too inclined to view future traffic development entirely upon the assumption that one road between two points is going to serve all traffic between these points for all time. I doubt that this is true. Alternate routes will be developed and traffic thus distributed. This will be good from many standpoints. It will prevent traffic congestion, allow the use of cheaper surfacings, accommodate more local traffic, provide a choice of routes, and allow for repairs and reconstruction without closing all available routes. The road problem of America is not to build a few boule-

yards: it is to build, maintain, and keep always open a transportation system.

TRAFFIC AND MAINTENANCE COSTS.

Wisconsin has now maintained her 5,000-mile State trunk highway system for three years and over 2,000 additional miles for one year, and we have gained some idea of the maintenance cost of various types. The condition of the various sections varied so much when they were taken over and the relative service given by the various sections and by the various types is so dissimilar that very little can be determined from an inspection of our figures of maintenance costs.

In 1919 the average cost of maintenance per mile for all types, surfaced and unsurfaced, was $254. The average cost of maintenance per mile by types (taken from a large number of sections) was as follows: Earth, $223; gravel, $212; water-bound macadam, $516; penetration macadam, $252; concrete, $337. Qualifying these figures, it would be only fair to say that the earth road maintenance included much heavy blade grader reconstruction, that the water-bound macadams had been allowed to get badly out of repair, and that all but $62 of the $337 for concrete was used in shoulder and ditch maintenance and in applying gravel to shoulders on 16-foot surfaces that were too narrow for the traffic.

As indicating the possible value of well-maintained gravel roads, we segregated nine very satisfactory patrol sections of gravel road and tabulated at least two separate traffic counts on each, a total of 23 traffic counts. The average count on these roads was 1,059 automobiles, 44 trucks, 21 motorcycles, and 48 horse-drawn vehicles per day. Weight was not taken. No effort was made to get maximum day counts. The roads in question gave excellent service every day in the year. The average cost per mile per section of maintaining these nine patrol sections was $263. These roads were not surface treated.

Our experience with gravel roads indicates that when well built of adequate widths with fine-crushed materials and well maintained their traffic limit is far higher than has been hitherto assumed.

The above figures may be of some interest although we have ourselves not been able to draw more than broad inference as to possible service limits and costs from them and other similar compilations.

THE TRAFFIC PROBLEM AND SERVICE VALUE.

In considering the relative service value of pavements, one can not disregard the matter of expediency. When considering a road problem and when determining an economical type to be used, there are always these factors to be considered:

(1) The expected traffic.
(2) The materials locally available.
(3) The funds available.
(4) The whole financial, traffic, and highway situation in the unit of government to be served.

This last factor is far the most important one in the whole situation and has been too often totally disregarded.

We have thought too little about the basic function of highways, which is, of course, to offer facilities for travel. We have been too prone to concentrate upon the consideration of a specific length of highway and upon an endeavor to economically design and build this length, rather than to concern ourselves with the more important traffic situation as a whole in the unit of government in which we operate.

We have been content to design and build a few miles of highway each year and to look forward into the far distant future with the hope that some day the contemplated system would be completed and traffic would be free to come and go as it pleased. We have closed our eyes to the fact that in the meantime we had on our hands scores or hundreds or thousands of miles of highway which are difficult for traffic at all times and impassable at some.

The highway authorities of each unit of government have before them a traffic problem. That is, they have a certain mileage of highways in a certain condition which now bear a certain amount of traffic, and the legitimate development of this traffic can be partly foreseen. They have available or they believe that there can be made available in a definite period, which they can select, a certain sum of money. Of course, the sum of money which may be made available is contingent upon certain circumstances usually beyond the control of the authorities. However, they can analyze their traffic problem, and their highways, and can assume the sum which they must have, and which they believe they can get, within a definite period of years, and can then determine about what should be done with this money, so as to give their clients, the public in that unit of government, the best result in traffic service during the designated period.

I don't know whether I make myself clear or not, but the point I am trying to drive home is this: Far more important than the mere selection of a truly economical type of construction for assumed conditions on a specific highway is the importance of determining upon that program of improvement which will be of the most benefit to the traffic in a designated area.

We are so obsessed with the schoolman's ideas of so-called true economics in pavement construction that we have been inclined to lose sight of the much more important economics of the traffic situation as it exists and may be expected to develop. We have had drilled into us the importance of economic design of specific stretches to such an extent that many of us have lost sight entirely of economic design for a traffic situation.

If unlimited funds, labor, and materials were always available, it might be possible that the schoolman is

right and that we should never build anything but the truly economical surface, but there is always a limit to the funds which can be made available or which can be expended in a specific term of years, and the true economics of pavement design is to find the solution which gives the least cost, not only for the construction and maintenance of the pavement, but in the carrying of traffic in the designated area within the designated period.

I may be able to make my idea clearer by giving a short illustration. Normal County has 200 miles of road of the greatest importance; 200 miles of secondary highways, important from the county standpoint; and 100 miles of strictly local highways, cared for by the local units of government.

Outside of the funds which can be made available for the general maintenance of this 800 miles of highway, it can be foreseen that in the next five years the total funds available for highway improvement in Normal County will be $4,000,000. Of the 200 miles of first-class highway, 50 miles have been surfaced in the past, and are still maintainable; 150 miles are earth, without hope of redemption. Of the 200 miles of less importance, 20 miles have been surfaced and 180 miles are earth. Of the 400 miles of local roads, all are earth. Traffic conditions are at present intolerable in the county. Each rain means a blockade; each spring and rainy season an absolute cessation of traffic, except by team, and that traffic is almost blocked.

The $4,000,000 available in the five years will, it is estimated, build 100 miles of the schoolman's economically correct highway. If the public officials determine to build this type of highway, at the end of five years there will be 230 miles of the first and second class highways (over 50 per cent of the whole) still unsurfaced. Isn't it plain that this answer can not be correct, regardless of the so-called economics of the specific instance? Isn't it plain that the public body controlling the money should most carefully consider the whole situation and spend the $4,000,000 in an effort to make at least passable the whole of the 400 miles of principal highways?

The schoolman will say that some of the money is wasted because a portion of the types selected to be built are not going to exist for 20 or 50 years, but the economic waste incident to the use of (in his opinion) uneconomic types is not a marker to the economic waste incident to the continued use of a largely unimproved system of highways. In other words, the loss to traffic by the prolongation of such a situation is usually infinitely more than the loss to the public due to the construction and maintenance of types requiring renewal after a term of years. The schoolman will say that if $4,000,000 isn't enough $10,000,000 or $20,000,000 should be raised, but our assumption is that the $4,000,000 is all that that community can possibly be sold within the given period, and the limit of selling to a community can be pretty well analyzed and defined by the public officials of the community.

Carried to a logical conclusion some one will say this plan means building largely temporary surfacings and later on building again. It does! And why not if that is the true economic solution?

Most of our railroads have been rebuilt more than once. The old railroad men thought not much further than the traffic there was in sight and the distance they had to build to accommodate this traffic. They then mustered all the money they could get or that the economics of the situation justified and built the best they could build with the funds available, usually using local materials to reduce the cost. But they built the whole way and carried traffic through immediately. As the business grew and intensified, and as the country developed so that it could pay for better transportation, thus justifying larger expenditure and better structures, the railroad was rebuilt. I believe we must proceed along exactly similar lines. First accommodate traffic, building to the money which can be made available, expecting that after the traffic is gotten through and the adjacent territory reaches fuller development the necessary betterments will follow.

From the mere standpoint of mechanical performance alone, only so many miles of high-class highway can be built each year. One can multiply this annual possible mechanical performance by 10 and in the ordinary State the total will not equal the number of miles of primary highways, now partly impassable, which should be made passable. In other words, the economically perfect system required to serve traffic properly can not possibly be built in 10 years in the average State. Are we in the meantime to allow the unbuilt portions to go totally unsurfaced and uncared for because we are crying for the moon of absolute perfection? Wisconsin is not waiting, and I miss my guess if many of the other largely unpaved States are going to wait for that millenium. Traffic must be served.

FEDERAL-AID TYPES AND SERVICE.

There has been considerable criticism to the effect that a large proportion of the Federal-aid construction is going into low-class structures and that therefore the funds are being wasted. (Q. E. D.)

Wisconsin is among the list of States which are summoned to the bar charged with building other than permanent highways with Federal and State money. We have no apologies to offer. About 19 per cent of our total mileage of Federal-aid construction will be concrete, 2 per cent macadam, 42 per cent gravel, and 37 per cent earth, with modifying surfacings to make it passable. Expressed in terms of money, about 40 per cent will go into concrete, the remainder into grading

and other types. Every project solved a traffic problem and freed a community from the bondage of years of impassability or danger. No one can tell me, nor can he tell the communities in which the work was done, that the money was wasted. Our critics themselves, if faced with the same problems, would have come to the same decisions.

I assume that other States have determined, as Wisconsin has, to serve traffic, rather than to slavishly adhere to certain so-called "permanent" types exclusively. Much of the criticism has come from those retained by certain pavement interests. Naturally if we do not construct their type of pavement we are necessarily wrong in their opinion.

We hope that all States will hold to safe ground and serve traffic now. Deviation from this policy is more apt to waste money than is adherence to it. Probably more Federal and State money has been wasted in prematurely building unnecessarily expensive types of surfacing than has been wasted in grading and building the lesser surfacings. After all, the one thing that is permanent about road work, the one thing that can not be done too well or too soon, is proper grading on correct locations. Those States that are feeling their way by doing much of this kind of work at places where traffic has been previously halted by grades or drainage conditions are not wasting money—they are truly investing it with profit.

COMMON SENSE VS. THE SLIDE RULE.

It may be inferred from this paper that it would take the brain of a Demosthenes, the genius of an Edison, and the engineering skill of a demigod to determine what pavements should be built given a condition, these theories, and a sum of money. Such is not the case. In four cases out of five a decision can be readily and quickly made when all surrounding facts and circumstances are known. What is required is, largely, common sense plus business judgment sufficient to grasp relative values. It is a matter of experience and judgment rather than of the slide rule and arithmetic. We have used too much higher mathematics and too little common sense. We have sought to set ourselves upon a pedestal of economic perfection and have closed our eyes to many of the surrounding circumstances, until many of us can not recognize a real economic fact when we meet it. The people are commencing to demand results rather than higher economics. They don't know much about pavement economics or relative economy of types, but they know when and where they were stuck in the mud and where they broke that last spring.

There are too many hundreds of millions of dollars invested in means of motor transportation, and too much pleasure, comfort, convenience, economy, and time saving depends upon their immediate, economical, and safe use for us to trifle with the facts as they exist. The owners of these vehicles demand service. They must be given it. This despite the fact that many manufacturers of motor vehicles persist in pursuing the ignis fatuus of highly centralized highway systems and of highly concentrated construction. Automobiles and motor trucks are owned on almost every square mile of territory and use every main highway. They can not serve or attain complete efficiency unless they can get through everywhere—now. Why their producers should deliberately work to limit their use offers to me an enigma impossible of solution.

It would be splendid if we could serve traffic immediately and always with the ultimate perfection of service, but it is mechanically impossible. Until we can so serve it we must meet the situation which exists and get the best result we can with the means at our command. We will not often be divinely right, we may sometimes build highways which our grandchildren will not use, but, after all, the people living right now also desire to live and to be happy and to run and jump and play and work.

Let's not worry so much about our predecessors or our successors; let's do our best for our contemporaries. Service value doesn't necessarily mean the ideal for the next decade; it may better mean service value right now, taking all things into consideration, including the living as well as those who may be expected to come after the living. After all, our children and our children's children will probably be able to take care of themselves. The children's children of other ages always have.

A county or State highway department should not exist merely to design and build a few miles of highway and a few culverts and bridges. It should exist to give transportation to its clients. It should strive to arrange the laws and their practice so as to give it now, not in 1950. The thing which we should strive to serve is highway traffic; we should be purveyors of transportation to His Majesty, the American people. Traffic must be served.

CONCLUSIONS.

I have rambled around without saying more that is worth while than the law allowed and I am ready to call it a day. I did not expect to prove anything definite when I started out, and I am not disappointed that I have not done so, even if you may be.

Summing up very briefly the meat there may be in this article we can say as follows:

(1) Service value must always be considered with reference to service cost.

(2) In comparing the relative service value of pavements, interest on the successive investments should be included in the gross cost.

(3) Soil, climatic, and rainfall conditions have a bearing on service value and should always be reckoned with.

(4) Width is an important factor in service and has a very large bearing on the conduct and maintenance cost of pavements, especially of the inferior types.

(5) Proper design and layout are important regardless of type, and poor design and layout seriously impair the service value of the best types.

(6) Traffic has a grave bearing on service and must be restricted and controlled in advance of construction plans.

(7) States must probably divide their roads into classes and name the limiting load for each class. All roads can not be made 15-ton roads every day in the year.

(8) It is not always possible to build the surface that will give the most economical service on the specific portion of highway, and it is not always advisable to do so.

(9) There can be no comparison of service values without assuming proper maintenance of all types of surface.

(10) Constant serviceability is supremely important, especially on main traveled highways, and will often determine the type and width of surface to be used.

(11) In planning improvements consideration of the traffic problem is of the gravest importance. Before any extensive program is laid out, the executives who control the construction should carefully survey the traffic situation and the highway conditions in their own and the surrounding units of Government and plan to meet them.

(12) We should probably seek to decentralize and spread intense traffic on several roads rather than seek to put it all on one.

(13) Expediency is not always wicked. It may sometimes be another name for common sense.

(14) It is better to travel over an uneconomically designed but passable highway system than not to be able to get through on a theoretically perfect one.

(15) The function of highways and of highway departments is to serve traffic and to furnish means of transportation.

(16) To-day's traffic must be served.

DISCUSSION OF MR. HIRST'S PAPER.

Frederick S. Greene, State highway commissioner, New York: Only two classes of pavement can be built with economy. They represent the two extremes of construction, and may be designated as the low and high type roads. The first class includes roads built of local materials; the second should include the most durable types of pavement known to the engineering profession. Between these classes falls the third class—the uneconomic class—composed of those intermediate pavements which cost a great deal more to build than the types which are constructed of local materials and which do not last long enough to pay for the extra cost. Such pavements, if you build enough miles of them, will bankrupt the State to maintain them.

The actual experience in the State of New York with pavements of this class, which includes water-bound macadam and bituminous macadam construction, is that they last seven and one-half years. We all understand that many of those pavements were built solely for horse-drawn traffic. If we had nothing but horse-drawn traffic to-day I would be a strong advocate of the water-bound pavement, but highway engineers know that the water-bound macadam pavement does not stand up under the action of the pneumatic tire, to say nothing of the truck tire. It has been pointed out that our railroads were built on the principle of the most miles for the least money, but no mention has been made of the fact that a history of our railroads shows that a great majority of them went into the hands of receivers and had to be reorganized. A State can not afford that.

NEW YORK EXPERIENCE.

The experience of New York with gravel roads has not been satisfactory. We have a great many miles of them, especially in Orange County, and the cost of keeping them passable is about $1,200 per mile per year. It has been pointed out that if gravel roads be built with a wide surface they will often give better service than a more durable type of pavement. We will all agree that a wide pavement, which permits the traffic to use it without forming ruts, will last longer than a 9-foot pavement on which, perforce, every vehicle uses the same rut. But the generalization which has been made fails to take into account a number of conditions which prevent the full realization of all the benefits of greater width. Such a condition exists, for example, when the roads are covered with snow. In a great many places it is only possible to clear a 9-foot track, and then, no matter how wide the road is, all vehicles are forced to travel practically in a single rut. Such condition will result in serious damage, even to the more durable types of roads. I have in mind, for example, the case of the road from Albany to New York, which is surfaced with asphalt block. The heavy snows last winter completely blocked this road for about four weeks. Finally a track was broken through and immediately a fleet of trucks began moving. The track was narrow and the trucks were forced to travel in a rut, and you can see to-day where the asphalt block has been worn down by the truck wheels with their equipment of chains. So, while I recognize that there are advantages in the use of wide surfaces.

such cases as that which I have described suggest that the general statement of the virtues of width can only be accepted with reservations.

NEW YORK'S NEW TYPE OF PAVEMENT.

There is a type of pavement which we are now building on our main lines which I think worth calling to your attention. It is new and we have not had time yet to determine what it is going to do, but from what we have seen of it, we think it is going to work out. The construction consists of 9 feet of reinforced concrete laid on each side of a center strip of the existing bituminous macadam, 6 feet wide. The concrete sides are built and the bituminous macadam in the center is repaired without disturbing traffic, and the result is a 24-foot pavement, made safe by the division of the traffic, which is effected by the strips. We find that the trucks and automobiles tend to hold to the concrete at the sides; that the center strip of bituminous macadam is used only by overtaking cars in passing the car ahead. For this reason we believe the macadam will last as long as the more expensive concrete. I think we can recommend this type of pavement to those States which are finding that the traffic has outgrown the existing pavements and especially if the roads at present are bituminous macadam. For those who are interested I will say that the first one we tried had 8-foot strips of concrete, which we found about a foot too narrow. We then built one with two 9-foot strips of concrete and a 5-foot strip in the center. This was not entirely successful because the 5-foot bituminous macadam strip in the center could not be properly rolled. To get a tandem roller to roll well the center strip should be 6 feet, and we have now definitely decided upon the 6-foot width for the center strip and the 9-foot width for the sides.

The Analysis and Preparation of Estimates for Road Construction.

H. J. KUELLING, Construction Engineer, Wisconsin State Highway Commission.

IN VIEW of the rapidly changing economic conditions in the past few years and the uncertainty as to future years, estimates have been giving and are going to give highway engineers considerable trouble. There has been and there will be great doubt as to whether or not bids should be accepted. The uncertainties have been very great in recent years and largely against the contractor. Apparently there is a reversal coming and the uncertainties will now be against the States. This means that it is all the more urgent that proper estimates be made on highway work.

The question of estimating will be discussed in this paper from the standpoint of a State department and not from the standpoint of an individual.

It is assumed by the writer that the economical type to be constructed has been previously selected. This statement is made because of the fact that in making estimates factors are very often uncovered which warrant a change in type. Since this subject is properly covered under other papers at this meeting, it will not be discussed here.

ENGINEER'S PRELIMINARY INVESTIGATIONS.

Before any figures are made on an estimate, the engineer must carefully analyze all conditions surrounding the work. In other words, he must spend time in seeking out all local information relative to every feature of the work. This local information may pertain to availability of materials; freight rates; railroad accommodations, as to sidings and train service; camp sites; water supply for these camps; availability of supplies for the camps, whether they come from merchants or farmers; the soil conditions, whether or not they are conducive to a small weather loss; whether the sand is so soft that it will interfere with the movement of his equipment, such as wheelers or wagons; the kind of clearing and grubbing he has, whether the trees are deep or flat rooted; marshes, if there are any, whether it is possible to work horses or equipment on them; the kind of grades that may be encountered in the work, which will have a bearing on the hauling of materials, or the pumping of water; in fact, he must seek information on a great variety of subjects.

In seeking knowledge of materials he must know the capabilities of commercial concerns to ship; whether they are in a position to get cars; whether they have the proper capacity to turn out the amount of material they are liable to contract for; whether their material is satisfactory; the business reputation of the concern, whether they will keep their word or not; that is, whether they will ship in accordance with promises, or whether they will ship to some one that comes along and offers them a higher price at a later date.

INQUIRY AS TO LOCAL MATERIALS.

Seeking information on local materials, the engineer must be even more careful, as he must know the kind of material available, the amount of it, especially if it is a gravel deposit, as these are likely to pinch out; he must know the cost of it, and he should have an option

on it, so that one contractor by getting this option can not bar others from bidding.

The mere investigation of materials in present use is not sufficient, as there are many cases where materials are being hauled several miles when there is a sufficiently good supply within a very short distance from the job. Entirely new and unknown sources of supply can be found in any State by a painstaking materials department. The changes of the freight rates, if there are any new increases, should be balanced against the extra distance that local materials can be hauled.

After an engineer has obtained or been furnished with all this local information he is still very much handicapped in making his estimate unless he has had considerable experience in actual construction. He should know the best methods of carrying on the work, what equipment to use, whether it be a grading or surfacing job.

COST INFORMATION FROM FORCE ACCOUNT.

With the amount of work that is being done and will be done by every State in the Union, the simplest, most practical, and only satisfactory way to get this cost information is for the various States to do some of their work by force account. The writer knows that some States can not legally do this, but believes that provision should be made so that they may. It will be surprising to many of you to find out the items that crop up and that must be paid for on a construction job. Some things are hard for an engineer to realize unless he has been through the mill, things which he is apt to criticize the contractor for including in his estimate. The State from which the writer comes has taken this stand for years past and has done a very great amount of certain types of work by force account. Up until the time of Federal construction this force account work was entirely in the hands of the county authorities and only under the general supervision of the State. Since the Federal construction began, the State has undertaken a number of jobs by day labor, and, in fact, in 25 of the 71 counties during the past season part of the work has been done in this way. This does not mean that the majority or even a large per cent of the work is done by force account, but enough is done so that the State will have first-hand and absolute knowledge of costs.

Owing to the variety of work and variety of conditions, it requires several jobs along different lines. For instance, on concrete road construction during the past season one job was run by day labor where the material was dumped on the subgrade and handled by wheelbarrows. This material was shipped in from commercial plants to a special siding; transferred by a clamshell bucket to side-dump cars on an electric railway, which ran along the highway, and dumped directly into the subgrade. In another case a local pit was developed and the material hauled to the road by trucks; it was then mixed and placed, the mixer being loaded with wheelbarrow. In a third case, a local pit was used, the concrete mixed at the pit, hauled in a mixed condition by industrial railway, and placed on the subgrade with a large crane.

In grading operations one job was undertaken in a sandy soil, one in gravelly soil, one in clay soil, still another in very stony ground. Some work was done by steam shovels and some by wheelers and fresnoes.

In a similar manner various kinds of gravel work were undertaken, some with sandy gravel, some with clay gravel, and some with gravel that would hardly be worthy of the name of gravel; in other words, it was really topsoil.

With an accurate cost analysis of all of this work at hand, we feel that we are in much better position to determine whether or not the bids submitted to us are satisfactory.

REGULAR SYSTEM FOR MAKING ESTIMATES.

After progressing this far in the making of an estimate, the writer believes that the States should have a regular system of making these estimates; in fact, he sees no reason why a committee from this organization could not develop a scheme or schemes for having all the States make their estimates in the same manner. This scheme, whatever it may be, should be after the fashion and, in fact, can well take the same form that a contractor should use. There is no reason why the drawing up of such estimate forms could not be done partly by the contractors or in conjunction with them.

This scheme of having the contractors work with the engineers has been tried out during the past year in Wisconsin with more or less success.

A year ago the State highway department called a two-day meeting of contractors, machinery men, material producers, and the engineers of the State. A very open discussion took place regarding the relations of all parties concerned. At this meeting a committee was appointed, which was instructed to draw up a form for making estimates. This committee was composed of five contractors, elected by the vote of the contractors themselves, one man from the aggregate producers, one man from the machinery manufacturers, three men from the county construction departments, and two from the State highway department. This gave a committee of five engineers, five contractors, and two others who were vitally interested in the meeting. The committee held three sessions and I assure you that they were sessions at which work was done. The contractors as a rule were frank in their statements and out of it grew an estimate form for one type of construction which seems to be fairly satisfactory to all concerned. No doubt it has many faults as yet, but it is a start in the right direction. This form is drawn up primarily for a concrete road job, but it can be very easily adjusted to other types of surfacing.

ESTIMATE FOR CONCRETE ROAD CONSTRUCTION.

The form as developed is divided into 16 subdivisions as follows: Cost of sidings, moving of equipment to the job, lost time in moving equipment, cement, clam shell and derrick supplies, fine aggregate, coarse aggregate, surfacing, camp loss, miscellaneous cost, contingencies, compensation and public liability insurance, bond cost, overhead, profit, charges for machinery and equipment. Each of these items is subdivided into as many divisions as were considered necessary by the committee. Most of these items you will readily see are somewhat easy to determine, but others are not. Only a few will be discussed here.

Overhead, the committee finally put on a percentage basis. For instance, in figuring a job the contractor or the engineer would have to estimate the percentage of the manager's time that would be required for the job and then charge up that percentage of his yearly salary to the job. The same procedure was followed with regard to office force, timekeepers, the expense of the manager, his office rent, supplies, etc.

Overhead also includes the corporation insurance, interest on the necessary working capital, and any dues that might have to be paid to associations.

Under the item "Profit" I might say that the committee had a rather heated argument. Naturally the contractors were anxious to obtain as much profit as possible and have the State officials agree to certain percentages. This, however, we refused to do, and the percent of profit was left blank for the contractor to fill in as he desired. What we were seeking primarily was to get everyone to make his estimates along the same line; we were willing to let the contractor be his own judge as to whether or not he could get the job with certain profits added on.

CHARGES FOR EQUIPMENT.

In the last item—charges for machinery and equipment—the committee had perhaps the most interesting discussions. Charges for surfacing, machinery, and equipment were worked out to certain percentages per mile of road constructed. For instance, under concrete pavers, we assume that the paver will build 30 miles of standard 18-foot road, at the end of which time it will be completely used up. The same result is obtained if we assume that it will build 24 miles and at the end of that time have a salvage value of 20 per cent of the original cost. With the 30 miles noted above, and an average per year of 6 miles, the life of the mixer would be five years. Depreciation, therefore, in five years equals 100 per cent. Repairs in five years at 10 per cent would equal 50 per cent of the original cost. Interest, storage, and insurance amount to 30 per cent of the original cost, making a total of 180 per cent of the total cost to be spread over 30 miles, or 6 per cent per mile. In other words, in figuring the charges for machinery for a standard 18-foot road, the contractor would merely multiply the number of miles by 6 per cent and take that percentage of the original cost of his paver as the amount to be charged to the particular job under estimation. In a similar manner, the committee arrived at percentages for various types of equipment used in the surfacing work.

Suggested charges for machinery and equipment used for camps, concrete paving, loading and unloading operations, including depreciation, interest on investment, storage, insurance, and all repairs, but not including fuel, are shown in Table 1.

TABLE 1.

Kind of equipment.	Charge rate per mile of 18-inch concrete.
	Per cent.
Road rollers	2–4
Paving mixers	6
Stationary mixers	5
Finishing machines	7
Sectional storage bins (material)	7
Clamshell crane	4
Stiff-leg derrick (material)	4
2 pumps	6
Pipe line (material)	6
Side forms (steel)	12
Side forms (wood)	27
Iron stakes	15
Automobiles, camp, and service, including operating costs	16
Canvas	10
Hose	16
Wheelbarrows	16
Concrete rollers	20
Mixer loaders (belt conveyor)	12
Wagon loaders	7
Camp equipment	8
Total	

NOTE.—The above total is to be entered in item 16 of the cost estimate for one-course concrete payment.

The percentage on grading and hauling equipment naturally could not be arranged by miles. It must be worked on a time basis and can not be as accurately determined as surfacing equipment because of the greater variation in quantity and kind of excavation in different jobs. Final percentages have not as yet been arrived at by the committee for these types. The committee did state that including depreciation, interest on investment, storage, insurance, and all repairs but, not including fuel, the percentage per operating day would vary from one-fourth to one-half of 1 per cent of the original cost, depending upon the kind of equipment.

There is no doubt that a continued use of this form will bring out points of weakness, but the writer believes it is a step in the right direction and that within a very few years standard forms of estimating will be in use for road work, and that there is no reason why the same forms can not be used by the contractors and by the engineers.

There is also no doubt that adjustments will have to be made for certain local conditions which are not covered. Where there is something to guide there is

no reason why the contractor and the engineer should not be a little more in harmony than they have been in some cases in the past.

Short cuts in estimating are needed and can be devised by State departments. Care should be taken, however, not to make these too short. No scheme will ever be devised or charts drawn so that a novice can make highway estimates. It is only by the use of brain and knowledge of conditions influencing costs that proper estimates can be made.

WISCONSIN COST ESTIMATE FORM.

Item.	Operation.		Total.	Per square yard.
1. Cost of sidings		$	$	$
2. Moving equipment to job	(*a*) Hauling and loading mixer, clamshell, pipe, pumps, tools, camp equipment, industrial equipment, teams, trucks, etc.			
	(*b*) Freight on above			
	(*c*) Unloading and hauling to job			
	(*d*) Moving overland (other than rail shipment)			
	(*e*) Cost of erection of camp including water supply, storage bins, derrick, etc			
	(*f*) Return of above equipment to storage			
	NOTE.—Item (*f*) is applicable only to job requiring whole season for completion or on last job of season.			
	Total			
3. Lost time in moving equipment	Number of days.....at.....per day			
	Lost time to cover lost time in tranist to job or between jobs or between different set ups on same job.			
4. Cement	Number of barrels in pavement			
	Cost per barrel f. o. b. destination			
	Cost of.....barrels at.....per barrel			
	Cost of unloading, hauling, and covering			
	Cost of storing and rehandling.....barrels			
	Insurance on stored cement and empty sacks			
	Sack loss			
	Freight return on empty sacks			
	Demurrage			
	Total cost of cement			
	Cost per barrel delivered on job			
5. Clamshell and derrick supplies	Fuel, oil, etc., only			
	(Do not include repairs.)			
6. Fine aggregate	Number of cubic yards, including waste			
	Cost per ton at pit or quarry			
	Cost per cubic yard at pit or quarry			
	Freight per ton			
	Freight per cubic yard			
	Hauling cost per cubic yard			
	Estimated demurrage, $....., divided by total yardage, give cost per cubic yard			
	Cost rehandling from stock pile, $....., divided by total yardage, gives cost per cubic yard.			
	Total cost per cubic yard on job			
	Total cost of.....cubic yards on job			
7. Coarse aggregate	Number of cubic yards, including waste			
	Cost per ton at pit or quarry			
	Cost per cubic yard at pit or quarry			
	Freight per ton			
	Freight per cubic yard			
	Hauling cost per cubic yard			
	Estimated demurrage, $....., divided by total yardage, gives cost per cubic yard			
	Rehandling from stock pile per cubic yard			
	Total cost per cubic yard on job			
	Total cost of.....cubic yard on job			
8. Surfacing	Preparation of subgrade			
	Cost of joint material on job			
	Cost of reinforcing metal on job			
	Labor, mixing, and placing concrete, including engineer, fireman, form setters, fine graders, wheelers, shovelers, cement men, puddlers, baling and sorting sacks, curing, covering, uncovering, finishers, water boy, watchmen, pump man, barricades, and lights.			
	Cost of hauling mixed concrete, including fuel, and depreciation on hauling equipment			
	Water supply and pumping, including labor, connecting pipe, setting pump, fuel for pump, disconnecting pipe, and drilling well.			
	Mixer supplies, fuel, and oil only			
	Miscellaneous supplies, such as boots, hardware, etc			
	Total			
9. Camp loss	Including loss on board of men on operating days as well as on idle days, loss on full time men not included in overhead, etc.			
	(Do not include depreciation on camp equipment.)			
10. Miscellaneous costs	(*a*) Cost of hiring and shipping in men	$		
	(*b*) Water rent			
	(*c*) Rent of grounds and buildings			
	(*d*) Cost of building crossovers			
	Total			
11. Contingencies	Delays due to railroad embargoes, strikes at pits, quarry, or job, material plant breakdown, machinery breakdown, failure of water supply, unusually bad weather, freezing of pipe line, etc.			
12. Compensation and public liability insurance.				
13. Bond cost	Personal or surety bonds			

WISCONSIN COST ESTIMATE FORM—Continued.

Item.	Operation.	Total.	Per square yard.
14. Overhead.	Per cent of manager's yearly salary	$	
	Per cent of yearly salary of stenographer and clerk		
	Per cent of yearly salary material man and timekeeper		
	Per cent of yearly expense of manager, including railroad fare, hotel bills, bidding cost, auto, etc.		
	Per cent of yearly office rent		
	Per cent of yearly office telephone and telegrams		
	Per cent of office supplies, miscellaneous		
	Corporation insurance		
	Interest on working capital not otherwise included		
	Association dues		
	Total		

SUMMARY OF COST ITEMS—ONE-COURSE CONCRETE PAVEMENTS.

Item.	Total.	Per square yard.
1. Cost of sidings		
2. Moving equipment to job		
3. Lost time of moving equipment		
4. Cement		
5. Clamshell and derrick supplies		
6. Fine aggregate		
7. Coarse aggregate		
8. Surfacing		
9. Camp loss		
10. Miscellaneous costs		
11. Contingencies		
12. Compensation and public liability insurance		
13. Bond cost		
14. Overhead		
15. Profit		
16. Charges for machinery and equipment (Taken from total of Table 1.—Do not include Table 2.)		
Total		

The Study and Treatment of the Different Subgrades and Foundations.

CHAS. M. UPHAM, Chief Engineer, Delaware State Highway Department.

THE subject of subgrade and foundation construction is not a new one for there are many evidences that attention has been given to this detail ever since the art of road building has been practised. In practically every instance, however, this detail of construction was masked under the name of "drainage," a detail always recognized as of great importance, much talked about, but not ordinarily practised .

A few years ago many of the failures in roads were type failures, which meant that the pavement did not have the inherent strength to withstand the demands of traffic, even though supported on a stable foundation or subgrade. In other words, the surface pavement broke down under the loads of traffic.

Although we have now developed road surfaces that satisfactorily carry the present-day traffic, if properly supported, we still find there are failures of these standard types.

During the period of lighter traffic many standard types of road surfaces were developed that carried the traffic satisfactorily, even on the less stable subgrades; but with the coming of the heavier types of vehicles, it was found that these standard types of pavement would carry the heavy traffic only over well-drained and stable subgrades.

While much has been said and a certain amount of research has been made on drainage problems, it is quite obvious that until recently the greater concerted study has been made on pavement surfaces, and comparatively little complete investigation has been carried on relative to stabilizing the subgrade or road foundation.

PROBLEM OF STABILIZING SUBGRADE.

With our present knowledge of permanent surfaces we can, within reasonable limits, compute the strength and resistance to traffic, provided we know the condition and nature of the subgrade, but when we inject the varying factors that influence the stability of the subgrade, the conditions present a new problem, one composed of many variables and difficult to solve. The high first cost of road construction and the heavy cost of road maintenance make necessary a determined effort to solve, if possible, the question of stabilizing the subgrade, no doubt the most complicated problem yet remaining in road building.

Some engineers have recognized for several years that different soils and soil conditions present varying degrees of stability in the subgrade. Various methods have been followed in the subgrade treatment, but, in general, standard pavements have been laid on subgrades of different degrees of stability. In some cases the subgrade has not been sufficiently firm to support the pavement and traffic, and in others it has been of such a nature that a cheaper pavement would have been sufficient. In either case, the result is uneconomic, and the failure to put an end to such conditions is not flattering to the highway engineering profession.

In this paper the pavement is considered the artificial surface, the road foundation as that part of the subgrade that has been replaced or treated, and the subgrade as that part of the road beneath the foundation.

In general, the strength of a pavement is a function of its depth; therefore, any increase in depth will materially strengthen the pavement. The foundation will probably never be as strong as the pavement, but the nearer it approaches this condition the greater will be the strength of the pavement, for the foundation will then act to a greater extent in assisting the pavement to resist traffic forces. The same holds true with regard to the subgrade in stabilizing the foundation, which in turn stabilizes the pavement.

WIDE RANGE OF SUBGRADE MATERIALS.

It would be practically impossible to classify all the various kinds of subgrade materials. The wide range is evident on roads that have failed. Many times a standard pavement has failed in spots or short lengths although the entire road has been subjected to the same traffic. Apparently this is due to the fact that the foundation or subgrade is not as stable in these places that have failed. These failures afford opportunities for the study of subgrade and foundation treatment as well as road-surface design.

An interesting example of this is a bituminous macadam road that has been failing at certain points for a long period. Most of the soil in this vicinity was easily drained, but further investigation revealed that wherever the failures occurred there was an impervious layer of clay, not more than an inch in thickness, and lying in a generally horizontal position which prevented the moisture from draining away from these points. Below this impervious layer of clay which retained the moisture was a sand that was easily drained, and that would have afforded a stable foundation or subgrade condition that would have undoubtedly prevented the pavement from failing.

Such mistakes as this could probably be prevented by means of a subgrade-testing instrument, of which there are several tentative designs. Some of these afford means of securing valuable data, but in general there is a great variation in the results obtained with them when different degrees of moisture are present in the subgrade. The variation may be as great as 200 per cent in some soils when the difference in the amount of moisture is not sufficient to be perceptible to the eye. Until it becomes possible to interpret these varying results more closely than we are able to at present, subgrade-testing instruments will have a very limited usefulness.

METHODS OF STABILIZING SUBGRADE.

At present the subgrade problem seems to resolve itself into a question of stabilizing the subgrade either by draining or excluding the moisture or constructing a foundation course. Whichever method is followed the result is simply to increase the effective depth of road surface or pavement, inasmuch as the stabilized foundation or subgrade will act as increased depth of road surface. The problem consists in deciding just how much should be spent in the drainage and how much should be spent in constructing a foundation.

It seems perfectly proper to assume that the bearing power or stability of most soils is increased by the removal of moisture, so our problem can be more easily solved if we minimize the amount of moisture in the subgrade. The moisture enters the subgrade from the surface in the form of rain; from the sides by seepage or horizontal capillarity; from the bottom by vertical capillarity; or, as in the case on grades, by following along impervious strata which intersect the road surface or foundation.

It is a simple matter to take care of the water that enters the subgrade from above, as this means simply the waterproofing of the surface and shoulders, and the results obtained will be far in excess of the effort and the cost.

The water introduced by side seepage or horizontal capillarity can be taken care of by an intercepting ditch or tile and stone drain. With this removed, the only other source of disturbing water is from below, and this is the difficult portion of the problem to solve.

In many soils capillarity will draw water from 2 to 5 feet in comparatively large quantities. Some authorities claim that the capillary action will extend many feet more. It is quite likely that this capillarity, assisted by the vibratory action of traffic, would cause sufficient moisture to rise to the subgrade to render it unstable. The amount of water which will be thus held against gravity and the rate at which it will be drawn from below depend upon the sizes of the pore spaces between the particles. If these are small the vertical movement of the water will be relatively rapid, and the amount of water the soil will hold against the attraction of gravity will be comparatively great. If the pores are large the movement of the water will be slow and the amount the soil will hold will be small. The knowledge of these phenomena has been applied in the many successful efforts which have been made to defeat the action of capillarity by placing a layer of coarse material of low capillary power beneath the pavement. The tendency is to prevent the moisture from rising above the layer, thereby giving greater stability to the

foundation, which is, in a degree, equivalent to increasing the thickness of the pavement.

Another method of preventing the rise of capillary water, which has occurred to some, is to fill the pore spaces with a waterproofing material. A number of experiments of this nature are now being conducted by the Bureau of Public Roads. The results are bound to be of much interest and great importance.

PRACTICAL EFFORTS TO STABILIZE.

Up to the present time, however, the practical efforts to stabilize the subgrade have involved the substitution of sand, crushed stone, or gravel for the unstable material of the natural subgrade. Not only do such materials prevent capillary water from rising, but they also add to the stability of the foundation by virtue of their higher bearing value. Naturally the most effective of these materials are the gravel and crushed stone.

The worst condition we are called upon to meet is that which obtains when the subgrade is saturated with moisture, which usually occurs during the spring thaw. If the ground has been frozen and is suddenly thawed, there is a layer of saturated subgrade directly above the frozen material. That this is the worst condition that may exist is evidenced by the general breaking up of the roads in the spring. Subdrainage under these circumstances is of little value. The condition is best overcome by open ditches allowing the water to run off as soon as the frozen material is melted.

If the conditions are such that the subgrade or foundation can not quickly dry out, the pavement, almost regardless of type, will have a tendency to fail. If the subgrade can not be quickly drained, one of the best methods of stabilizing the construction is to build up a foundation with a material capable of high bearing value and capable of carrying the load.

In some States it is customary to build a foundation using rocks varying in size from 3 to 15 inches. Although this method of treatment is costly, it is very effective, and many roads with these foundations have been carrying heavy traffic although surfaced with only a medium heavy pavement. While a foundation of this sort can stand considerable moisture, still a constant effort should be made to exclude moisture.

There are undoubtedly many other practices that could be followed that would assist in the stabilizing of subgrades. It has been shown that plowing or breaking up the earth will cause it to retain moisture. Therefore, it would seem that the reverse should be true, that to exclude moisture the subgrade should be thoroughly rolled and compacted.

It can not be hoped that a single paper can more than touch the salient facts of this subject, as great questions are yet to be solved. The treatment of subgrades will depend on the results found in the experiments on the bearing power of soils, on experiments to prevent capillary action, on results obtained in underdrain experiments. In other words, there are many questions that must be solved, or partially solved, before the question of economically treating the subgrade and foundation can be completed.

Our present knowledge of the subject assures us that the stability of the subgrade or foundation depends upon the amount of moisture in the subgrade. The sandy or gravelly soils are more stable, but in order to stabilize the clay soils they must be kept dry or replaced with different material. The design of the subgrade or foundation will always depend upon the drainage, and the engineering problem is to decide whether it is more economic to treat or replace the subgrade material, or to provide elaborate drainage, or a combination of the two.

DISCUSSION OF MR. UPHAM'S PAPER.

J. H. Johnston, division engineer, Massachusetts: "Therefore when we build, let us think that we build forever. Let it not be for present delight, nor for present use alone. Let it be such work as our descendants will thank us for, and let us think, as we lay stone on stone, that a time is to come when those stones will be held sacred because our hands have touched them, and that men will say as they look upon the labor, and wrought substance of them, 'See this our fathers did for us.'"

We all hope, with Ruskin, to build for posterity, and our choice of methods will determine whether we shall build roads or only debts. In Massachusetts it has taken 26 years to spend $40,000,000, and I gasp at the thought of the enormous programs now laid out by many of the States. It is easy to fall on one of the two horns of the highway dilemma either by building roads so cheaply that they will not stand or by building roads at such great cost that the interest on the investment will be far more than the cost of maintaining a much greater mileage of serviceable highway.

It has been said that the only permanent features of a road are its alignment and its grade, but this is only a half-truth; for we have seen many lines and grades changed, and the survival of ancient roads has taught us that foundations can be permanent when properly constructed.

A properly built road seldom wears out except upon the surface. We have had many miles of such road torn out because changing conditions make necessary wider surface, less camber, banking of curves, or changes in grade and alignment, and we do not know what the future has in store for us.

The success of a road can not be judged for several years, and in the meantime the designer of the structure may suppose he is on the right track and continue an erroneous practice, building a large amount of work that must eventually fail. If the failure is due to improper foundation, the only remedy is to tear it all out and start afresh. Unfortunately, foundations appear to be so little understood that failure is too often attributed to surface causes and the poor work

continued. Long experience and careful thought are essential to recognize cause and effect. For these reasons it has seemed to me a serious mistake to separate construction and maintenance departments, for if the man who built the road maintains it he has a chance to learn from his mistakes. For years I made it a practice every spring to locate all frost breaks and soft places on the roads in my charge. I endeavored in each case to learn the cause of failure, to apply remedies, and watch results. I am, therefore, a strong advocate of the most substantial foundations, and if anything must be skimped, my advice is cheapen the surface, for that is easily repaired.

While it is universally agreed that foundation and drainage are essential to permanency in a road, there is too often a mistaken impression as to what constitutes proper foundations and drainage.

PREFERABLE TREATMENT OF SUBGRADE.

The preferable treatment of subgrade and foundation under a concrete road depends largely on whether or not cracks are considered a serious detriment and what outlay is thought justifiable to eliminate them. In western Massachusetts the frost penetrates the ground to depths of 6 feet. The soil conditions are so variable that very uneven frost distortion occurs, and to treat a subgrade to insure a bearing so uniform as to avoid cracking a rigid concrete surface would require a bed of clean gravel, sand, cinders, stone, or similar porous material at least 24 inches deep, using side drains with pipe at bottom to carry off the ground water and deep gutters or ditches at each side of the road to take care of the surface water. Such construction would cost from $3.50 to $4 per square yard for the foundation and drains alone, and for the concrete, about $3.20 more, making a total of from $6.70 to $7.20 per square yard, or about $90,000 a mile, including grading and culverts, for an 18-foot roadway.

Even then you could not entirely eliminate, but would only minimize, the cracks. Is it worth the price to get rid of cracks that are objectionable only from an aesthetic standpoint? We have a concrete road in the Berkshires built over only 2 inches of gravel (and this was used merely to insure a clean subgrade on which to place the 6-inch concrete slab) which has cracked badly, but after four years rides as smoothly as the best new surface. We have other concrete roads where the foundation of the 6-inch slab consists of 12 inches of cinders, gravel, or stone, with 2-foot side drains on the edges. There is no apparent difference in the amount of cracking over these various materials, and though, in places the surface is badly cracked, the road is smooth to ride upon. The concrete road problem seems to me, therefore, mainly a question of the value received for the money expended.

While there is a very broad field for the concrete road, the road problem as a whole must be solved by utilizing any suitable local materials that may be available, and using a minimum amount of such more costly imported materials as may be needed.

EXPERIENCE IN MASSACHUSETTS.

Perhaps a résumé of our experience in Massachusetts may be of interest. The Massachusetts highway commission started its first State road construction in August, 1894. In October, 1894, I began my career as a State highway official. In those days water-bound macadam was thought to be the acme of perfection for State road construction, and it was built 15 feet wide, 6 inches at the center and 5 inches thick at the edges after rolling. Later we reduced the thickness to 4 inches at the edges. All loam pockets were excavated to a depth of 12 inches below subgrade and back-filled with gravel. Over soft clayey soil we laid a Telford base 8 inches in depth, with a sub-base of gravel 6 inches deep, and over the Telford surfaced with crushed stone 4 inches deep after rolling. At the edges of the Telford we constructed a French drain 3.5 feet deep. Where the Telford and drains were properly built the road stood well, and many such sections are in excellent condition to-day, after more than 20 years' service. It was thought, however, that such construction was too expensive, and to reduce the cost we first cut down the depth of the Telford to 6 inches of stone, over 2 inches of gravel sub-base, and later built without Telford base, except in the most extreme conditions, on the theory that if the macadam cut through it could be readily strengthened by adding more crushed stone on top. There never was a greater fallacy. I have added 12 inches of fresh stone over a 6-inch macadam and within three years have seen the traffic cut through, and this was in the old days, when 3 tons at 3 miles per hour was the greatest strain put on the road. This was tried not merely once, but many times, and never with success. The same experience and failure was repeated by the Army engineers during the late war. They were obliged to abandon the practice and use heavy stone for foundation purposes. It is therefore proved that ordinary crushed stone up to 2½ inches in diameter has very little value as a foundation. I desire to emphasize this because I find the practice still has followers, and they are surely wasting the public money.

We thought French drains would dry out the subgrade and result in sufficient added stability to permit the soil to bear up a 6-inch macadam without additional foundation. We built many miles of such roads but did not get the desired result. We tried gravel, 6 inches to 12 inches in depth, under crushed stone and with French drains, but such roads did not stand except in locations where the natural soil conditions were favorable. Gravel is an uncertain material; gravel suitable for this purpose is scarce and expensive—in many parts of our State more expensive than stone—and though excellent when used in proper combination with large stone will not give permanent results with only the ordinary crushed stone sizes over it.

TRYING THE V DRAIN.

We then tried the V drain, using stone up to 8 inches in largest diameter and building the drain 18 inches

deep at the center and 4 inches deep at the edges, and over this we placed 4 inches of crushed stone. The drain was not always the full width of the hardened surface. Such a base held up the roads but resulted in uneven frost action, as, of course, the deep center would not heave as much as the edges; and at times such roads would have a concave cross section. This action was not a serious detriment with a water-bound macadam surface under horse-drawn traffic, but when the motor vehicles made necessary a more rigid surface, that would be broken up under the unequal distortion of the base, we were obliged to change our methods. It had been supposed the V design (the deep center) was necessary to act as a drain to collect the water, which was then tapped off at convenient outlets; but for the last 10 years I have been building, with a subgrade of level cross section, a stone foundation (using the same large stone), 6 inches deep at the edges and 10 inches deep at the center, the voids filled with gravel and the whole rolled until absolutely firm. Where soft bottom is found we use a sub-base of 4 to 6 inches of gravel; where extremely bad soil conditions are met these dimensions are increased to make the punishment fit the crime. For the stone base it is specified that over half of the mass shall consist of stone fragments not less than 4 inches or more than 8 inches in their largest diameters, with the largest stones at the bottom, laid on their broadest bearing, and smaller stone on top to chink the voids. Such foundations are holding up our roads under a present traffic of 2,000 to 2,500 vehicles daily, with loads as great as 20 tons hauled at 20 miles an hour, and without distortion serious enough to break up the bituminized surfaces placed over them. Except where there are springs, we do not use French drains with this stone base, but place outlets to drain the base at suitable places.

We have built many miles of road with such a base, filled the voids with gravel and placed over it an average of only 2 inches of crushed stone, bound with 1 gallon of tar per square yard, and such roads have stood up since 1913 under traffic which has constantly increased to a present daily average of 1,500 to 2,000 vehicles, with a maintenance cost averaging less than $100 per mile per year. There are, of course, places where field stone is scarce and good gravel plentiful. In such regions we have roads built with 12 inches or more of gravel as a base, covered with 8 inches of crushed stone, but such construction is much more expensive than the heavy-stone base and will not stand as well.

NO STANDARD TREATMENT.

I. W. Patterson, chief engineer, Rhode Island: In discussing the subject, I believe that we must first acknowledge that, on account of varying natural conditions, there can be no standard treatment of subgrades. We have, as in New England, the condition where the subgrades are entirely variable; they may vary decidedly at intervals of from 50 to 100 feet in places. In certain sections of the Middle West, on the other hand, we have a uniformly bad subsoil; and we have the road builders' paradises of New Jersey and Florida, where subsoil troubles are almost unknown. It is useless, therefore, to attempt to arrive at uniformity of subgrade treatment. Each section must work out its individual problem to the best of its ability.

Where a uniform subsoil prevails the failures in various places may be of distinctly different types. They may be complete failure of comparatively long sections, or they may take the form of the frost boil, which is not known in the South.

Whatever the form that the failure takes, there are particular reasons which cause it to take that form, and a study of the conditions is necessary to determine the cause before the condition can be rectified. It seems to me, therefore, that it would be well to give some attention to methods of diagnosing troubles.

DIAGNOSING THE TROUBLE.

The practice we employ is to make an inspection of our roads during a period of thaw in the winter months and again during the spring. The winter investigation is made for the purpose of ascertaining the effects of frost, which are in evidence then and at no other time. The purpose of the examination in the spring is to study the conditions which exist when the subsoil is completely saturated with water, which is not always the case in the winter.

In making such examinations we must not confine ourselves to the consideration of the soils alone. Oftentimes our troubles are not due to qualities inherent in the soil but to other causes. In New England, for instance, some of our worst troubles are due to ledges of rock which outcrop in the subgrade. We often find that what is apparently a perfectly stable soil will give all sorts of trouble locally during the winter months. A diagnosis of the trouble in a great many cases discloses bars of ledge which prevent the flow of water from the high points to the low, and cause areas of the soil to become thoroughly saturated. Such areas are especially liable to give trouble in winter and spring. But whatever the cause of the trouble, it seems to me that the best chance of discovering it is by means of thorough examinations at the two seasons I have described.

Having located the trouble we should consider whether it is better economy to attempt to design a pavement which will bridge across the weak places where the conditions are not uniform, or whether we should develop the subgrade by the use of cheap materials so that a pavement which can be built at a minimum cost will hold up over it.

Another point which should be considered is the very intimate relation between the establishment of grades and the elimination of subsoil troubles. There are places where serious subsoil difficulties might be eliminated in the grading at minimum cost by simply superimposing over the troublesome section a layer of permeable material of low capillarity excavated from some near-by point. It seems wrong to me always to attempt to decide definitely upon the grades and then plan the foundations. The two operations should be carried along together to secure economy.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. *105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

* Department supply exhausted.

FARMERS' BULLETINS.

F. B. 338. Macadam Roads.
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. *89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States. 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
Vol. II, No. 15. State Highway Mileage and Expenditures in the United States in 1918. 15c.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted

CLEMSON COLLEGE LIBRARY

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 34 WASHINGTON, D. C. FEBRUARY, 1921

NEW JERSEY FEDERAL-AID PROJECT NO. 2—WINDSOR TO HEIGHTSTOWN

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Researches Affecting the Design of Roads for Heavy Motor Traffic . . 3
A. T. Goldbeck.

Load Limitations for Primary and Secondary Roads 11
C. J. Bennett.

Modification of Contracts to Meet Present Conditions 16
W. R. Neel.

Organization of a State Road Maintenance Department 19
J. N. Mackall.

Report of Committee on Use and Care of Federal Equipment . . . 23

Federal-Aid Allowances 27

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
SUBSCRIPTION PRICE, $1.50 PER YEAR

RESEARCHES AFFECTING THE DESIGN OF ROADS FOR HEAVY MOTOR TRUCKS

A. T. GOLDBECK, Engineer of Tests, Bureau of Public Roads.

THE heavy motor truck which has come upon us within the past few years, and which promises to increase in numbers, imposes an entirely new problem of design and a far more complicated problem than has ever existed before. We no longer need regard the abrasive wear of the higher types of roads with much concern, for by proper maintenance we can take care of abrasion. The development of the design for light, fast-moving, rubber-tired traffic may also be considered as practically completed. But the problem of how to design a road to carry heavy concentrated loads under all conditions, without fear of structural failure, remains unsolved, and this is our most important problem in road design to-day. The governing traffic unit in the present-day design is the heavy motor truck, and when we have built our road to take care of this unit under all conditions we need not fear for the adequacy of the road for any other class of traffic.

FAILURES OF ROAD FROM HEAVY TRUCKS.

Before considering what researches should be undertaken to gain the necessary information to serve as a basis for adequate road design for heavy motor trucks it will be well to stop and review briefly the character of failures that have resulted in some of our roads through use of heavy trucks. General observation of roads that have failed under heavy trucks invariably reveals what has been termed a "structural failure." Such a failure involves not only the road slab but also the subgrade. It is brought about by a combination of exceedingly heavy loads and a very soft condition of the subgrade. Had the poor subgrade condition not existed, complete structural failure would not in general have resulted. Failures of this kind have involved entire stretches of roads or in many cases have occurred in spots, which, coupled with evidences of incipient failure of the road as a whole, have led to the conclusion that a short period of still more unfavorable subgrade conditions would probably cause general failure of the entire road surface. Where exceedingly heavy units of traffic are not in general use and where the subgrade is of good supporting value, complete structural failures are hard to find, but they are numerous where this condition does exist. Minor defects, such as cracks, which might be regarded as incipient failure, are brought about in many cases by the action of heavy traffic. It is recognized, of course, that there are in addition other causes for initial failure of the road. It is recognized, too, that heavy traffic produces other defects in the road surface depending on its type, but such defects are insignificant and can be taken care of by maintenance or comparatively inexpensive resurfacing in the future.

It will not be amiss to review the mechanics involved in the design of roads in so far as this is possible. When we consider the design of any structure built to carry loads we must know with reasonable accuracy what will be the maximum load. The motor truck as it is commonly built at the present time has its weight distributed on four wheels, with as much as 80 per cent of the gross load carried on the two rear wheels. The road surface, then, must support four concentrated loads, the maximum concentration being not uncommonly 12,000 pounds on a single wheel. This is not a quiescent load, for the truck is in motion and the road surface is never perfectly smooth. The sprung and unsprung weights of the vehicle are set into vertical motion, and thus instead of a static force we have a suddenly applied load or even an impact. The concentrated load imposed on the road is distributed to the underlying subgrade. If the wearing surface possesses slab strength, or if it does not possess slab strength but is of comparatively great thickness, the concentrated load is distributed over a considerable area on the subgrade and becomes a load of varying intensity, with highest intensity directly under each wheel and gradually diminishing away from the wheel.

SUBGRADE SUPPORT IS NOT CONSTANT.

Soils composing the subgrades of roads are limited in their bearing value, particularly when they have become soaked with water. It is a matter of common observation that certain soils when water-soaked approach a state of fluidity and will hardly support the lightest load. It will readily be appreciated that heavy concentrated wheel loads may impose pressures on the subgrade of greater magnitude than the bearing value of the soil. Under such conditions the subgrade material naturally deforms and immediately great stress is thrown into the wearing surface through flexure. When the subgrade is of very high bearing value, as it invariably is when dry, it yields practically not at all under light pressures distributed to it by the wearing surface, and under such conditions the flexural stress under the load is likewise small.

Enough investigations have been made thus far to indicate that the support offered by the road subgrade is anything but constant and anything but uniform,

It has been shown very definitely that the subgrade support changes with the varying moisture content and with the effect of frost. In fact, instances have been observed in which the road surface has been left without support over large areas. Under such conditions considerable stress must be produced in a rigid slab under the action of traffic. Such conditions are brought about, however, mainly through inadequate preparation of the subgrade and through inadequate drainage.

From the foregoing brief discussion it would seem that our road-design problem of to-day is very decidedly a problem of structural design, and that it does not stop at the design of the wearing surface alone, but that it involves the proper design of the underlying subgrade. We must adequately support the slab and we must design the slab so that it will not fail under heavy loads.

When one approaches a problem of design of any structure the knowledge required involves, first, knowledge of the forces to be imposed upon that structure; second, knowledge of the manner of distribution of stress throughout the structure; third, knowledge of the behavior of the materials used when subjected to stress. Researches for the adequate design of roads for heavy motor trucks must include, then:

1. Investigations of the forces applied to the road surface by heavy motor trucks.
2. A determination of the distribution of these forces through the wearing surface and subgrade.
3. An investigation of the behavior of the road surface and subgrade materials under the action of these forces and other forces produced by natural causes such as temperature and moisture changes.

In the present discussion it is not the purpose to outline in detail the various investigations which must be made in connection with the three broad general problems just mentioned. It will be well, however, to call attention to a number of these researches in order to indicate in a general way why they are necessary and how they might be carried out.

INVESTIGATION OF THE FORCES ON THE ROAD SURFACE PRODUCED BY HEAVY MOTOR TRUCKS.

It is apparent to anyone who has stood on a road surface during the passage of a fast-moving heavy truck that the surface is being subjected to a considerable force—a force far in excess of the static weight of the vehicle; and this is evidenced by the vibrations produced under the action of the truck. It is apparent that the road is being subjected to a variable force as the truck rolls along and that in many places severe impacts are delivered by the wheels of the trucks. Just why should this be so? It would seem that with road surfaces as smooth as we are able to make them under the present-day methods of finishing, trucks should roll along with practically no vibration; but it is surprising just how much effect a slight inequality will produce in causing the truck wheel to actually leave the surface.

For illustration, it has been observed that the rear wheel of a heavy Army truck moving at 20 miles per hour apparently cleared the road surface by at least 1 inch in passing over a slight inequality due to a small excess of bituminous filler in an expansion joint. But what force exists on the road surface when the truck wheel lands under such conditions, and why should there be any extraordinary force produced? Let it be remembered that when a truck wheel is clear of the road surface there is an enormous force in the truck springs tending to bring it back to the surface. In consequence of the spring compression, when the wheel again comes into contact it has attained high vertical velocity. The truck tire is compressed as soon as again in contact with the road surface, which then exerts an upward force, finally reducing the vertical velocity to zero. In other words, the force existing between the road surface and the tire has decelerated the downward vertical velocity of the portion of the truck beneath the springs.

Now, it is an old law in physics that force is equal to mass times acceleration, and since the mass of the unsprung portion of the truck is brought to rest vertically on the road surface, or decelerated, there must have been required a reaction between the road surface and the tire at least equal to the mass of the unsprung portion times the deceleration of that portion; and in addition to this force there must be added the force due to the compression of the spring. The longer the time required to bring the unsprung portion to rest vertically the smaller becomes the deceleration and consequently the lower the force. This explains why pneumatic tires are apt to prove so much lighter in their destructive effect on the road than solid tires, and likewise explains immediately why steel tires have such a destructive effect.

If in the future we plan to design our roads in a purely rational manner, is it not plain that we must find out all there is to be known of the various forces acting upon the road? The heavy forces of traffic are vitally important. Very complete investigations should be made of the various kinds of motor vehicles when fitted with various kinds of tires, for the tires play an important part in easing the effect of the blow. Such researches[1] have already been carried out extensively by the Bureau of Public Roads and thousands of tests have been made. These tests which have been made under artificial impact conditions should be followed by impact tests made on actual roads in order to obtain an idea of the relative destructive effect of traffic due to varying degrees of smoothness. Such in-

[1] A report of these tests will be printed in the March number of this magazine.

vestigations will shortly be made by the Bureau of Public Roads using an apparatus which permits of drawing a curve from which the vertical acceleration of the sprung and unsprung portions of the motor vehicle may be obtained and thus the forces on the road surface may be calculated. This apparatus is now partially successful, and it is believed it will be possible to make it produce very satisfactory results. It would seem that the results of tests of this kind at some future date might be used in motor-truck legislation, but before this is done tests will be necessary to show the relation between the force to be expected from motor trucks and the destructive effects produced by these forces.

A DETERMINATION OF THE DISTRIBUTION OF FORCES THROUGH THE WEARING SURFACE AND UNDERLYING SUBGRADE.

Having determined what forces are exerted on the road, the next logical step in our efforts at the development of rational design leads us to an effort to find out how the surfacing and subgrade are stressed under these loads. These are research problems for the future and they present many experimental difficulties. At the present time we are able to determine stress distribution under static loads, and we can also determine distribution of pressure on the subgrade, and both of these investigations should be made. It would be well to work toward the development of apparatus for measuring deformation under impact, and also apparatus for measuring subgrade pressure under impact.

An investigation of the behavior of the road surface and subgrade materials under action of forces.—As in any type of structure we must know how stresses are distributed when that structure is subjected to external forces before we can hope rationally to design the structure. When we consider that the road slab is supported by the subgrade in a nonuniform and continually varying manner, and when it is considered that if the slab were subjected to static loads alone the difficulties would still be enormous, how much more difficult must be the problem before us when we attempt to consider impact. However, rational design should be our goal of the future, and an effort should be made to measure the stress distribution in the slab under the various loading conditions to which it is subjected, including not only traffic loads but the loads produced by natural forces. Again, we must not neglect the stress due to impact, and suitable means must be devised for obtaining the stress distribution under the action of suddenly applied forces.

Pressures distributed to the subgrade.—A matter about which there is comparatively little knowledge is that of just how heavy truck loads are distributed to underlying subgrades. It goes without saying that if we ever hope to reach the stage of rational design we must be able to say definitely something of the law of distribution of concentrated loads to the underlying subgrade. Very little actual research has been performed on the distribution of pressures through materials, primarily because of the extreme difficulty of performing investigations of this character. A few results have been obtained, however, showing how concentrated loads are distributed through a concrete slab to the subgrade, and it is felt that we now at least have an apparatus that is satisfactory for that purpose. It would seem that a very important research would be that of determining the distribution of pressure intensity between the subgrade and the road slab under the action of heavy loads on the slab. The slabs should be of sufficient range in thickness and design, and the subgrade should vary in its characteristics. Such an investigation should also be made when the slab is subjected to impact. Unfortunately, however, there is now no available apparatus for determining subgrade pressures under impact, although it should be possible to devise such an apparatus.

THE EFFECT OF FORCES ON THE ROAD STRUCTURE.

We have seen that roads are subjected to impact; then why is it not a logical procedure to subject road surfaces of different design to the heaviest impact that is to be expected from actual motor trucks? That is the plan now being followed in a large series of tests in which a number of variations of designs are being used. The specimens are being subjected to the impact of a special impact machine designed to give the same impact given by the rear wheel of a 5-ton truck. By careful observation the results of impact tests of this character and the relative load-supporting value of various types of pavements is secured, and, moreover, such tests can be made when the road surfaces are supported on subgrades of varying supporting capacity. From the results of the tests thus far completed it has been observed that there are astounding differences in the resistance to impact of slabs of different design. Such experiments should be carried out on a sufficiently wide range of subgrades, and should be followed by experimental stretches of road subjected to actual traffic so as to tie in the results of the impact test with actual traffic conditions. It is planned to accomplish this by subjecting actual roads to impact through the use of an impact machine mounted on a motor truck.

Investigations of the subgrade material.—General observation leads us to the belief that low bearing value in the subgrade greatly decreased the load-carrying capacity of the road structure. The question naturally arises, then, what characteristics do soils possess which render them of high or low bearing value? And, further, what steps must be taken to improve the bearing value of the subgrade? It becomes necessary to make laboratory tests on soils to determine the physical characteristics which cause them to have low bearing value.

The following procedure is being carried out at the present time: Samples of soil are taken from the subgrade in the vicinity of places where the road has failed very badly. Similar samples are also taken from parts of the same road that have not failed under the same traffic. All of the supporting data are obtained in the field, giving complete information as to the topography and drainage. Samples of soil are then analyzed in the laboratory, determinations being made of their physical characteristics, including mechanical analysis, percentage of clay, silt, colloidal content, and bearing value when the soils are saturated and when they are in various stages of saturation. In this way it is hoped to establish what are the physical characteristics of soils making for good or bad support.

The question of how to improve the bearing value of soils should likewise be investigated. No laboratory tests are needed to prove that high water content in soils makes for low bearing value, and it goes without saying that if we could properly eliminate water from the subgrade we would always have adequate support for our roads. Investigations should, therefore, be made on drainage to the end that means will be established for adequately draining subgrades composed of the various kinds of materials and under all conditions of topography.

The field of research to be covered for the rational design of roads to successfully carry heavy traffic under all conditions has many ramifications and can only be treated in a very general way. The following table, however, gives a list of the researches, the information from which should lead to the actual design of our roads:

RESEARCHES LEADING TO THE ADEQUATE DESIGN OF ROADS FOR HEAVY MOTOR TRUCKS.

1. Determination of static forces and impacts of motor trucks on roads, including the effect of—
   - (*a*) Sprung and unsprung weight distribution.
   - (*b*) Tires and cushion wheels.
   - (*c*) Springs.
   - (*d*) Speed.
   - (*e*) Kind and degree of roughness of road.
2. A determination of the distribution of static force and impact through the road surface and subgrade, including effect of—
   - A. Surface:
     - (*a*) Load.
     - (*b*) Variations in materials (bituminous, concrete, brick, etc.).
     - (*c*) Variations in design (rigid slab *v.* non-rigid type). (Reinforced *v.* plain concrete.)
     - (*d*) Variations in thickness, etc.
     - (*e*) Variations in subgrade.
   - B. Subgrade:
     - (*a*) Variations in wearing surface.
     - (*b*) Variations in load.
     - (*c*) Variations in physical characteristics.
     - (*d*) Variations in moisture.
3. Investigations of road surface and subgrade materials.

NOTE.—This includes researches of the physical and chemical characteristics of materials and their combinations to determine their suitability and to establish such physical constants as may be needed in design.

The above researches are deemed necessary in order to place the design of roads on a rational basis, and it is only possible to carry out such a program in the shortest possible time through the coordination of all the agencies of the country capable of performing such work.

ACCELERATED TESTS.

In the meantime we are building roads and we want information very badly that will tell not how to arrive at the design of a road rationally but that will tell us with reasonable accuracy whether our road is going to prove adequate for the traffic. We should pursue our long series of tests to establish the fundamentals of road design, but we want approximate information immediately on what to expect of various designs. That is the reason for accelerated tests on actual roads. Such tests are not absolute, but they do give us much needed information quickly, and they point to certain limitations in the various designs. Among such tests may be classed the impact tests of road slabs now being carried out by the Bureau of Public Roads and the accelerated wear tests in which different types of roads are subjected to the same wearing device.

DISCUSSION OF MR. GOLDBECK'S PAPER.

WM. D. UHLER, Chief Engineer, Pennsylvania.

IT would be hard to question any of the writer's conclusions on the design of road slabs, inasmuch as he has covered in detail the effect which heavy, fast-moving traffic would produce on road slabs and surfaces—namely, (1) the induction of shear, (2) of bending (thus causing very considerable stresses due to bending moment), (3) abrasive action, and finally (4) such stresses as may be occasioned by vibratory action set up in the slab. We all know that as a rule heavy shearing stresses induce incipient surface cracking or rutting, heavy bending stresses ultimately result in unduly wavy pavements, abrasive action ruptures the top surface, and vibratory action causes general rupture of the slab throughout its entirety, the last named being perhaps the most dangerous in very thin slabs, even though the subgrade conditions are ideal.

We should not lose sight of the fact, however, that there are many other features which should be given

as much consideration as the purely theoretical factors of structural design. It is possible that we may not be justified, economically, in working toward an ideal pavement slab or section under all conditions. I mean that it may be quite apparent, under given conditions, that inferior materials may be used to form a base for a road surface in which the stresses might be indeterminate.

It would seem, primarily, that the design of the road slab or section should be based upon the subgrade conditions. Thus it follows that the subgrade should be subjected to certain tests, which will in the future become standardized, just prior to the placing of the slab. Such tests presuppose the protection of the subgrade from weakening influences such as saturation, which would ultimately lead to failure, due either to flow of the subgrade or frost action.

It would naturally follow that future practice will lead to what we might term the design of the subgrade in the field and to a refusal to accept it until it passes the tests which the engineer feels will warrant him in concluding that the slab which is to be used will be capable of so distributing the pressure that the coefficient of elasticity of the slab will not be exceeded.

PREPARING SUITABLE SUBGRADE CONDITIONS.

In order to carry this out, the engineer must become thoroughly conversant with the methods which may be used in arriving at suitable subgrade conditions, viz:

(1) The design of the proper type of drainage system. This may consist of tile underdrains, stone underdrains (the underdrains being of either longitudinal or lateral types); the selection of a proper open-ditch design, or the selection of a paved ditch which will readily handle surface waters and keep the subgrade dry, or, finally, gravel or broken stone sub-bases.

(2) Some treatment of soils which will reduce their capillarity. It is realized that up to this time no economical method has been developed to remedy this condition.

(3) A study of the proper compaction of deep fills to lessen the possibilities of slab failures.

(4) Treatment of variable subgrades, such as old road surfaces, by plowing, harrowing, etc., so that when rerolled they will have the same relative coefficient of elasticity over their entire surface.

My reason for discussing these features is to bring out the fact that it is relatively just as important to design the subgrade as it is to design the pavement, and I feel that to the lack of a subgrade design may be laid the major portion of such failures as have occurred in the past, and, further, that it is not practical to attempt to design an economic slab until a subgrade is formed which will provide a suitable foundation.

TESTS ARE NOT YET CONCLUSIVE.

It would seem that it is particularly undesirable at this time to accept any tests or conclusions which might point to an accepted or recommended practice in the design of slabs, because such tests as have been carried out do not furnish substantial evidence which might reasonably point to an economic design. In this connection it is pertinent and germane to question the desirability of accepting as conclusive at this time any tabulation, prepared for the guidance of engineers and highway officials, which shows the relative suitability of the many types of pavement surfaces now in use in this country for heavy-truck traffic. In a recent tabulation it was stated that vitrified brick on concrete is considered the highest or best type of pavement for heavy motor-truck traffic. This conclusion was undoubtedly arrived at through laboratory tests. Actual field experience shows that this type of pavement must be considered among the most unsatisfactory pavements for heavy motor-truck traffic. The wearing surface on this type of pavement is not under the direct control of the engineer in the field. Due to irregularities of surface, brought about either by poor details of construction or by nonuniformity of the brick units forming the surface, exceptionally heavy impact stresses are created.

It is unfortunate that many of the tests which have been conducted have been premised upon sections which, from an economic standpoint, are not comparable; for instance, it is shown that the relative resisting qualities of a grouted brick surface on a 6-inch concrete base closely approximate those of a grouted brick on a 4-inch concrete base, placed under practically the same working conditions. Extreme care should be taken, therefore, in attempting to interpret these tests, and we should always keep in mind not only the relative resisting qualities of the types but their relative costs in dollars and cents. We should not forget that the laboratory test is but one means of attempting to solve the problem, and we should not lose sight of the fact that the test of actual experience with roads which are carrying heavy traffic is probably at this time the most consistent and conservative way of judging of the permanence of any particular type of pavement.

Pennsylvania, at this time, has a yearly registration of over 570,000 motor vehicles. Our roads are subjected to an exceedingly heavy punishment, particularly from excessive truck loading, and the conclusions arrived at above are based on actual engineering observations and studies in the field.

NEED OF CONSERVATIVE INTERPRETATION.

It would seem desirable at this time to call attention to the need of a conservative interpretation of tests. A pamphlet issued not long ago entitled "Clouds on the Transportation Horizon" endeavors to create the impression that it is not the heaviest type of truck which causes failures of our road surfaces, but, rather, that it is the light, fast-moving truck traffic. It would seem particularly unwise at this time to endeavor to reach this conclusion. These conditions might hold for one

season of the year, but are inapplicable to other seasons; for instance, a heavy, slow-moving load will undoubtedly result in failures of road surfaces during the early spring months when our road surfaces are, as it were, held in unstable equilibrium. Having in mind the various points which have been raised, I might state that our studies in Pennsylvania have led us toward the preparation of more uniform subgrades, and that our new specifications will eliminate the storage of all construction materials on the subgrade or require their storage in piles which shall at all times be at least 1,000 feet in advance of the actual placing of the surfacing materials. It might be of further interest to state that we have at this time six different schemes for drainage which are being used on all construction work, the particular system adopted being premised on actual investigation in the field.

In conclusion, I wish to congratulate Mr. Goldbeck on the able presentation he has made of the necessity for detailed researches in connection with this most vital and interesting topic, and it is to be hoped that the States will cooperate with the Bureau of Public Roads in the fullest measure, in its endeavors to carry out further researches along broad, practical, economical lines in the field; for it is by these methods only that we can arrive at a definite conclusion.

DISCUSSION OF MR. GOLDBECK'S PAPER.

By CLIFFORD OLDER, Chief Highway Engineer, Illinois.

It is a matter of common observation that as rapidly as paved roads are built the traffic using such roads increases enormously and almost invariably changes in character. When roads are built through agricultural or industrial territory it soon becomes evident that truck traffic is the chief destructive element, and as the most insistent demand for paved roads comes largely from such territory it is evident that rural pavements, except in unusual cases, must be designed for truck traffic.

It seems evident from even a casual observation of well-constructed rural pavements of rigid type that wear is no longer an important factor. As an example, Milwaukee Avenue, leading northwesterly from Chicago and just north of the city limits, carries from 2,500 to 3,000 mixed vehicles on week days and from 10,000 to 15,000 passenger cars on Sundays. This section was paved with concrete in 1915. It is not difficult to distinguish in places the original hand float marks, and it is altogether probable that practically all of the slight wear to be observed occurred during the first year or two of its use before steel-tired wagons were replaced by rubber-tired trucks and automobiles. Very careful measurements have been made during the past six months and no measureable wear can be detected.

EXPANSION AND CONTRACTION.

Expansion of the pavement due to any cause may be provided for either by inserting transverse joints of a yielding material or may practically be neglected if the pavement is sufficiently strong safely to resist the compressive forces induced by expansion. Expansion joints have been omitted in Illinois practice for five years. The few "blow-ups" that have occurred were repaired at much less expense than the interest on the money saved by the omission of the joints.

It would seem that no economical means have yet been devised to prevent transverse cracking due to the contraction of the pavement slab, except by the construction of artificial joints. Longitudinal cracks, due perhaps largely to frost action, seem still to be with us, although such cracks can probably be largely controlled by substituting longitudinal dividing planes.

The only visible evidence that our well-constructed rigid pavements may have a limited life is found in the appearance and widening of cracks, the occurrence of "blow-ups," and the occurrence of breaks due to excessive loads.

Apparently, transverse cracks or joints and possibly longitudinal cracks or joints also will always be a factor to be considered. Observation of brick and so-called soft-top pavements laid on concrete bases show that at least the bases of such pavements are no more free from cracks or joints than are concrete pavements. In such pavements, however, the cracks are not as conspicuous and may not require the same class of maintenance. It may safely be stated that cracks and joints, if properly cared for, affect the life of a rigid slab only as they may affect its strength or load-carrying capacity.

CORNERS ARE CRITICAL POINTS.

It is not necessary to apply mathematical calculations to develop the fact that a load applied near the center of a comparatively large unbroken pavement slab would produce much lower stresses therein than would be produced were the same load applied at or near the edge of the same slab. Further, it is evident that a load applied at the edge of an unbroken slab would not produce stresses comparable with those produced by the same load placed at a corner formed by cracks or joints. It is obvious that these are bending stresses and the resisting moment of the slab, especially as regards tensile stresses, is of vital importance. This theory was advanced in an article by the writer published in Engineering News-Record, May 18, 1919.

Regardless of the supporting capacity of the subgrade, it is the corners formed by the intersection of cracks and joints with each other and with the edges

of the pavement that constitute the weak points of rigid slab pavements. On the Illinois roads which carry truck traffic many broken corners have been observed in all types of rigid pavements, and only in a single instance has a traffic break been observed that was not readily traceable to the piecemeal breaking down of corners or narrow strips formed by longitudinal cracks making acute angles with the edge of the slab.

The exception was an asphalt-top pavement on a 1:3:5 concrete base, 4 inches thick at the sides and 5 inches thick at the center, which broke into small pieces under excessive truck loads. An examination of the base showed that the transverse strength of the base had been exceeded, not merely at the corners but also at the edges and near the center of large slabs. No concrete slab or base 6 inches or more in thickness has broken except at the corners.

Until we are able to control completely the cracking of rigid slabs it seems obvious that we must design the entire slab to carry the imposed loads at the weak points—the corners.

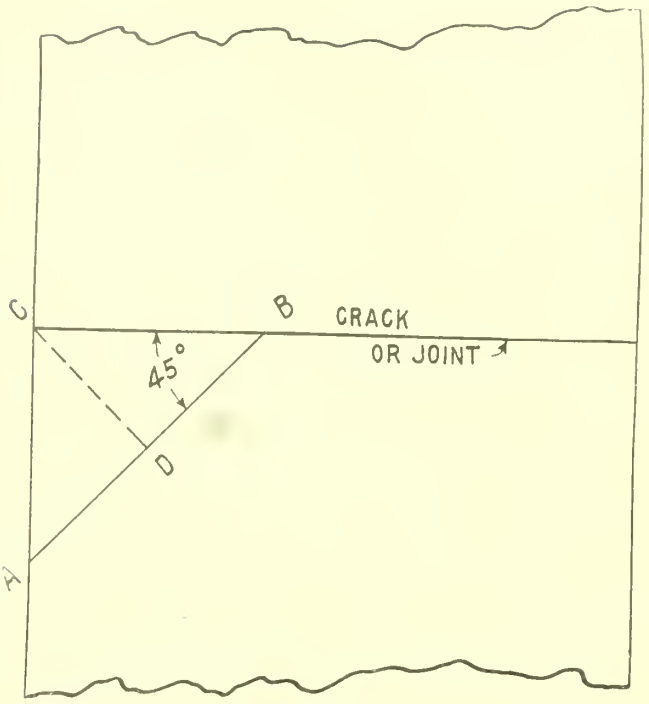


Fig. 1.

SUBGRADE SUPPORT OF CORNERS.

Preliminary investigations by the Illinois highway department confirm the findings of the Bureau of Public Roads as to the greatly reduced supporting capacity of clay soils as the percentage of moisture increases.

Further investigations have developed the following data:

Illinois corn-belt clay soil rapidly absorbs sufficient moisture to render its supporting capacity near the surface almost nil.

Under the center of an 18-foot concrete slab one month old, laid on a subgrade on which no rain had fallen for 6 weeks, the subgrade soil was found to contain about 17 per cent moisture after a 2-days drizzling rain.

The subgrade under pavements laid on both cut and fill sections with 6-foot earth shoulders, but without tile drains, appeared practically saturated when investigated 3 or more days after the beginning of a rainy period.

A very narrow crack will permit the passage of large volumes of water to the subgrade. The practical saturation of the subgrade soil for several feet each side of a narrow crack is but a matter of a few hours' time during a period of continuous rain or melting snow.

The repeated passage of heavy wheel loads over corners, even when such corners are supported by comparatively dry, clay subgrades, causes, within certain limits, a progressive depression of the soil under the corner.

These investigations, although not as yet extended enough to be conclusive, indicate strongly that it may be difficult, if not economically impracticable, by any system of drainage, combined possibly with a waterproofing of the subgrade, to maintain a clay subgrade dry enough to afford any reliable support to the corners.

In the following tentative method of design it is proposed that subgrade support be neglected as a definite factor.

TENTATIVE METHOD OF DESIGN.

Assumptions:

As corners are obviously weaker than other portions of the slab, only the corners may be considered.

Until erratic cracking can be controlled it is necessary to build all portions of the slab on the basis of corner strength.

Considerations of economy prohibit the use of reinforcing steel as a strength factor.

Until conclusive observations of the dependable supporting capacity of subgrade soils can be made, taking into account the possible control of the moisture content, support of corners by the subgrade should be practically neglected.

When bituminous-filled expansion joints are omitted, and frequent dividing planes with dowel pins or tongue-and-groove joints are used so that erratic transverse cracks may not be expected to open materially, a wheel load placed on one side of a joint or crack near a corner may be considered as divided equally between the adjacent corners or slabs. (It is suggested that contraction joints be formed by galvanized or painted corrugated sheet metal or metal sheets so bent as to provide tongue-and-groove joints.)

When bituminous-filled expansion joints are used, or when frequent contraction joints are not used, thus increasing the probability of the wide separation of occasional cracks, the entire maximum wheel load should be considered as supported by one corner.

The effect of impact on a rigid slab constructed strictly in accordance with strict specifications as to

surface smoothness may be considered as offset by subgrade support. The improbability of the maximum wheel load ever being applied at a point causing maximum moment provides an additional factor of safety.

Observation of the pointer of an Ames dial set to measure the deflection of corners failed to show visible vibration during the close passage of moving truck wheels. These tests were made on a Federal-aid section of concrete road constructed by contract, with no attempt to secure unusual smoothness. It is possible, although not probable, that impact vibration, too rapid to be detected by ordinary means, may have been present.

In the design it is only necessary to consider tensile fiber stress.

Referring to the sketch, figure 1, W=maximum wheel load, one-half of which is to be considered as applied at C.

x=CD=distance from load to critical section= moment arm.

AB=$2x$, since the critical section is located on a line making an angle of 45° with the edges of the slab.

M=moment of force applied to one corner=$\frac{1}{2}$ Wx.

S=allowable tensile stress of the material forming the upper surface of the transverse strength element of the slab.

d=depth of slab.

c=distance from neutral axis to outer fibre=$\frac{1}{2}$ d.

I=Moment of inertia of the cross section of the slab at the critical section=$\frac{2xd^3}{12}$

Substituting these values in the formula $S=\frac{Mc}{I}$, this formula reduces to $S=\frac{1.5\,W}{d^2}$, or $d=\sqrt{\frac{1.5\,W}{S}}$

Assuming the whole load carried by one corner only, this formula would become $S=\frac{3\,W}{d^2}$ or $d=\sqrt{\frac{3\,W}{S}}$

It is to be noted that at right-angle corners the critical sections may be at any distance from the loaded point. In practice the subgrade under the corners of a slab carrying a double line of heavy traffic will be depressed more than elsewhere leaving subgrade support some distance back.

Perhaps it would be safer to consider the entire wheel load as carried by one corner, although the few experiments so far made in Illinois show equal deflections of adjacent corners when such corners are formed by narrow cracks or doweled dividing planes, the load being imposed upon one corner only.

If one corner only is considered as carrying the whole load, then the above formula is undoubtedly on the safe side if the pavement is built with a sufficiently smooth surface to reduce impact to a negligible quantity.

We have had under observation a concrete road, 6 inches thick at the sides and 8 inches thick at the center, constructed with a 1:2:3½ wet mix, roller, and belt finish. No expansion joints were used in the construction. Header boards provided dividing planes at the end of each day's work. The breaks were all at corners formed by rather wide cracks, and were definitely known to have been caused by certain trucks hauling crushed stone. The load on each of the rear wheels of these trucks was computed to be 9,000 pounds.

In accordance with the above formula and assuming no subgrade support or mutual support of adjacent corners, a wheel load of 9,000 pounds applied at the corner would produce, in a 6-inch slab, a fiber stress of about 750 pounds per square inch.

The actual stress developed at the right-angle corners was no doubt less than this, as it would have been impossible for the entire wheel load to come upon the extreme corner.

Only 12 corners have been broken, out of several hundred which existed in the length of road used by the trucks. The modulus of rupture of the concrete is not known, but probably it is between 500 and 600 pounds per square inch.

The fact that all corners were not broken was probably due to partial subgrade support, partial mutual support of adjacent corners, but largely to the fact that the loaded trucks traveled close to the edge of the 18-foot slab only when passing empty trucks going in the opposite direction. There was no traffic on the road aside from the stone trucks. The loading of the corners, therefore, occurred only at infrequent intervals when trucks passed at cracks or joints. A total of about 1,500 loads were hauled. This instance would seem to afford a rough check on the formula.

FURTHER INVESTIGATION UNDER WAY.

The further investigation of slab deflections and stresses, the effect of mix, type of wearing surface, etc., on modulus of rupture, the supporting capacity of soils with varying moisture content, the variation of the moisture content and supporting capacity of such soils under pavement slabs at different seasons and with different types of drainage systems, the compression of soils under repeated loads, the possibility of largely controlling the location of longitudinal and transverse cracks by sheet-metal divisions, the mutual support of adjacent slabs afforded by friction on the rough surface of cracks, the mutual support of adjacent slabs which may be secured by artificial means at dividing planes, and other items affecting the transverse supporting capacity of pavement slabs is being carried on in connection with a 2-mile test road which is being constructed by the Illinois highway department, and at favorable points on old pavements.

The test road was designed to determine as far as possible the load-supporting capacity of various types of pavements, laid on a uniform subgrade, as affected

by thickness and other elements governing transverse strength.

Great care was used in selecting the site in order that uniform subgrade, alignment, and grade conditions might prevail. The road will be closed to public traffic until the test is complete. Upon completion and curing of the pavement the road will be subjected to an artificial truck traffic, gradually increasing in weight until the legal load limit as established in Illinois has been exceeded by about 50 per cent.

Four principal types of pavement are being used—macadam base with brick and bituminous concrete wearing surface; concrete base with bituminous top; concrete base with monolithic and soft filled brick top; and one-course concrete.

In the main each test section is 200 feet long. The series of sections for each type begins with a thickness roughly estimated as equivalent to 4 inches of concrete and increases to the approximate equivalent of 9 inches of concrete.

The behavior of the subgrade before and during loading will be observed by means of pressure cells secured from the United States Bureau of Public Roads, and by means of special observation devices consisting essentially of sections of iron pipe set in the slab, protected at the top oy removable plugs, and containing a loose brass disk in contact with the subgrade. By means of an inner pipe this disk is forced down when the pavement deflects under load and remains in contact with the subgrade as the slab recovers. Thus a means is provided to observe with an Ames dial the permanent or temporary depression of the subgrade.

The supporting capacity of the subgrade may also be observed at any time by loading the disk and by removing the disk moisture samples may be obtained.

A descriptive bulletin is being prepared which will give in detail the design of the various sections, methods and control of construction, description and use of special apparatus, observations under way and contemplated, plan of loading, etc. It is expected that the loading will be started in July or August, 1921.

It is hoped that when completed the above briefly described investigations may aid materially in determining a rational method for the design of rigid slabs. In the meantime the foregoing provisional method of design is suggested for use.

Load Limitations for Primary and Secondary Roads

C. J. BENNETT, State Highway Commissioner, Connecticut.

THE topic under discussion is directly connected with the consideration of the efficiency of highway transportation, a subject which heretofore has not been very seriously studied by the majority of highway engineers.

Preliminary to discussion of this topic it may be said that most of us are faced in a greater or less degree with an abnormally heavy highway traffic which, from various causes, has been placed upon our highways regardless of their suitability or strength. We know that we shall be required to carry tremendous loads over the highways. We do not know the magnitude of these loads, nor have we any assurance of a limit, either to the weight of the units or to the total volume of traffic to which our highways will be subjected.

It seems evident that before we can intelligently design highways, bridges, or other structures, we must know the character, amount, weight, and speed of vehicles which we are expected to accommodate. It would also seem axiomatic that it is not fair to ask for the development of highway systems everywhere to carry the extreme loads which are now being borne by motor trucks. This would mean the expenditure of vast sums of money for the accommodation of a limited number of units. Hence, we develop a need for a separation of highways into classes. For purposes of discussion we shall assume that highways may be divided in two classes as outlined in the subject of this article.

CLASSIFICATION OF HIGHWAYS.

In order to indicate more clearly the scope of the problem, we must define the terms which we are using. In other words, we must answer the question, What are primary and what secondary highways. For purposes of discussion and not determination, let us roughly define primary highways as those highways connecting centers of industry, whether manufacturing or agricultural, over which must be carried commercial products in large quantities continuously at all seasons of the year. Secondary highways may be said to include all other highways than those classified as primary, or perhaps those roads which are required to carry traffic of a secondary importance, whether passenger cars or light commercial vehicles. These highways are those which eventually must serve all parts of the community and aid in the progress and development of the Nation.

Roughly speaking, the routes thus classified should be so correlated and so designed as to provide for the most efficient use of the motor vehicle for commercial purposes without infringing upon the field of other methods of transportation, such as rail or water. Pro-

vision must be made in design that the primary highway systems may be expanded as the need arises without undue loss in original investment. Here we have a very large field for investigation. It is not herein intended to give an absolute solution of the problem nor to cover all of this investigation. We have suggested the need for limitation of load, and the impossibility of improving all highways to the maximum requirement has been superficially indicated.

LIMITATIONS SHOULD BE NATIONAL.

The restriction of loads under these suggested limitations should be further considered. In the first place, the subject must be approached not as one concerning any particular State or group of States, or any small unit of government. It must be studied as affecting the administration of all highway departments throughout the United States. In other words, any limitations which are placed upon loads should be universal and apply to all motor vehicles whether operated in Maine or California. This, of course, implies the passage of National or uniform State laws. It can easily be seen from this statement that the problem is not easy of solution. It requires broader study and stronger cooperation than we have yet been able to accomplish. It demands a knowledge of motor-truck operation that is not yet available. It suggests numerous lines of thought which can be followed by conclusions which, when reached, can be collected together and used as information to impose restrictions as to weight and as data for design. The subject is not alone one of load limitation, but should be enlarged to cover any limitations which may be placed upon the operation of motors and loads such as speed, width, height, length, number of units in a train, design of mechanism, and myriads of other things that will develop as we pursue our way.

These are, of course, generalities. We must have a starting point. We must have some specific suggestions as to the limits of the loads which may be operated on routes designated as primary and on those defined as secondary. Of course, for the purpose of securing a definite point of beginning, we must go into what has already been done along these lines.

LIMITATIONS DECIDED UPON AT CHICAGO.

Referring to a discussion held in 1918 in Chicago, at which both the highway officials and the motor-truck manufacturers were represented, certain limitations of motor vehicles were decided. So far as the writer is concerned, nothing has developed since that time which would modify the conclusions there reached. These conclusions have to do with the maximum weights, widths, and heights of motor vehicles, and are consequently applicable only to the primary routes which we have defined above as those which may be considered as the main media of highway transportation. The limitations thus set were a maximum gross weight of 28,000 pounds, or 800 pounds per inch width of solid rubber tire. The width of the load was to be 108 inches, and the maximum height 12 feet. These restrictions would allow the use of a 5-ton truck as now built, loaded to capacity, and it would seem that this is the maximum weight of truck which may be efficient for primary highways. We must realize that this limitation is not for to-day alone but for the future as well, and should last for the life of the road.

Until, however, we have finally completed our primary highway systems, we must modify these restrictions somewhat. In other words, we must provide for the operation of these units only at such times as they will subject the road surface to the minimum wear. We must provide some method of still further restricting these loads at seasons of the year when the maximum damage to highway surfaces occurs. This power, again, should be universal and in the hands of those intrusted with the care and upkeep of highways. Means must be provided whereby the maximum loads will be operated only on the primary systems.

REGULATIONS FOR SECONDARY HIGHWAYS.

Considering further the question of secondary highways, here we have a still larger subject, for we must provide a standard of construction and maintenance for all other highways than primary routes in order to carry a specified load. This portion of the problem is much more complicated and harder of solution than the former portion, for we must realize that we are dealing with the far larger amount of traffic over the secondary routes than over the primary routes. In other words, as we increase the restrictions on loads or amount of load, we are approaching closely to the maximum number of motor vehicles operated.

For illustration, taking a certain 20,000 commercial motor vehicles licensed, only 750 of these vehicles are in excess of 4 tons capacity, while upward of 16,000 are less than 2 tons capacity, so that our restrictions for a secondary system of highways must be such that we shall secure the maximum efficient operation of the larger number of commercial motor vehicles. For this reason it is suggested that the maximum allowable total load for secondary highways shall be 12,000 pounds unless the load is carried on pneumatic tires, when it may be increased to 15,000 pounds. We may inquire why this increase may be made. Roughly, it is thought, and experiment tends to prove, that the pneumatic tire, properly inflated, does less damage to the highway surface than the solid tire, especially when the solid tire is partly worn. It is hoped that these assumptions may be checked in the future and more formulæ developed which will be exact rather than empirical. None of the limitations suggested have taken into consideration the passenger car, as either

system properly designed should properly accommodate the passenger car when load alone is considered.

In general consideration of the subject as a whole we must therefore conclude that limitations are necessary whatever they may be, but that the information at hand is not sufficiently definite to say what the effect of certain loads may be. A future study of this topic is imperative and is being made.

NECESSITY TO ENFORCE LIMITATIONS.

Again, as a general conclusion to this discussion, we must admit that if any limitation of loads is determined upon it must be enforced. There is no use or reason in attempting to establish restrictions on traffic with no intention or means of enforcement. A study of this subject would not be complete, or even partially so, without a suggestion of the methods to be followed in seeing that the rules laid down are carried out. The writer has knowledge of many instances where laws restricting weights are written without attempt to enforce. It is evident that such a practice is almost of no use.

In order that the universal rules suggested above may be properly carried out, there will be need for cooperation between the different States in the enforcement of their licensing rules and in checking up the vehicles registered. Consequently, it appears that any highway system should be developed in cooperation with the motor-vehicle department, and a proper policing department provided whereby it may be thoroughly established that the laws regarding the use of the highway by loads are absolutely carried out. These departments should all be built up on a standard scheme of organization.

As outlined above, this is not an attempt to solve once and for all a problem which has been presented to us. This is impossible. There are many steps ahead of us in the proper solution of this difficulty. We have only begun to realize the magnitude of the traffic which we must accommodate. Repeating again for emphasis, the problem is large and broad in its scope; its factors are unknown. We have a long, tedious course of study before us until we can set down the actual facts to prove our contentions regarding the limitation of loads. To this we must add a sincere effort to prove to the different agencies interested in highway transportation the need of some sensible and reasonable restrictions to be enforced.

DISCUSSION OF MR BENNETT'S PAPER.

Thomas Maddock, State highway engineer, Arizona: If no load limitation is provided we shall inevitably have a lot of valuable paving destroyed by heavy loads on the one hand, and on the other some paving will be built heavier than is needed to carry those loads which are finally agreed upon as being proper.

If enough States limit truck loading, the manufacturers will build accordingly, as it is obvious that they can not manufacture a few large trucks economically. Apparently there is no possibility of trucks competing with railroads in carrying heavy loads long distances. Trucks can not compete economically even with narrow-gauge railroads, where quantity tonnage is concerned, even with their tracks, i. e. the highways, built and maintained by the public. Unrestrained by any law, except the law of supply and demand and the carrying capacity of rubber, the great majority of trucks now built are of not over 5-ton capacity. In other words, existing conditions have already restricted maximum truck capacity.

There is a limit to the labor and capital which the public can devote to road building. Such expenditure of the limited funds as will procure the greatest good for the greatest number is certainly the only course it is practicable to take at this time. This will mean the construction of large mileage of a rational type of road rather than the building of an indestructible but decreased mileage of highways capable of carrying the occasional giant vehicle.

FOR SINGLE ROAD LIMIT.

I do not agree with the suggestion that different load limits be adopted for primary and secondary roads. It is nearly impossible to build a good secondary road without thereby creating a primary road. I believe the primary thoroughfares should be broader than the secondary roads; but the difference in width of primary and secondary roads is not under discussion. In ability to carry load I believe the two classes of roads should measure up to the same standard. The difference in the cost of the small drainage structures capable of carrying say, a 28,000-pound load as against a 15,000-pound load, is negligible in permanent construction. Large bridges are so expensive under any circumstances as to be relatively few in number. This concentrates traffic on them which makes them become part of primary roads. The surface of pavements is probably worn more by the number of vehicles than by the few extra heavy loads which use the road.

The elimination of the bridges and the width and surface of paving leaves the strength of the paving slab as the controlling feature in load limitations. The strength of these slabs increases with the depth of paving much faster than the cost, and I should prefer

to invest the State's money in the greater depth required to paying the salaries of three 8-hour shifts of policemen to stand at the innumerable intersections of primary and secondary roads and weigh every vehicle which some one desires to drive on to the latter. If our secondary roads are built strong enough, they can be widened at any time and easily become primary roads. On roads already built the load limitation should be determined by each road's carrying capacity rather than by some general classification as primary and secondary.

The prestige of the Bureau of Public Roads should be sufficient to secure the passage of a uniform load law in each State upon request. If not, the Government's interest in the investment of Federal funds warrants the bureau in demanding that the Government's equity be protected by restricting the use of roads to properly loaded vehicles.

I think the load limitation suggested by Mr. Bennett—that is, 28,000 pounds for primary roads—while probably somewhat higher than is absolutely needed at present, provides well for the future and should be adopted. To my mind, however, it is not a question of adopting this load limitation, but of deciding upon some load limitation. There are too many unknowns in the road equation. This one can and should be eliminated.

MASSACHUSETTS RAISES TRUCK FEES.

James W. Synan, commissioner, Massachusetts: No doubt the Eastern States find themselves bothered more by the great truck problem than many of the Western States. Our commission has charge of the motor-vehicle department as well as the road-building department, so, like Commissioner Bennett, we have had our eyes opened to a realization of the troubles that are coming. Massachusetts is attempting to meet the problem by charging a license fee somewhat proportionate to the damage done by the truck to the road. We have reached the point where we do not believe that the ordinary individual should be taxed to take care of the comparatively few people who are benefited, in a broad sense, by these tremendous vehicles. We find that every road in our State built previous to five or six years ago will have to be rebuilt to accommodate the comparatively few people who insist upon operating trucks with loads weighing 12 to 15 tons or more.

For many years, in Massachusetts, trucks paid a fee of $5, no matter how big they were or how much weight they carried. After some agitation the fee was increased, but we could only get it increased to $8 for a 2-ton truck, $11 for a 3-ton, $14 for the 4-ton, and $17 for the 5-ton truck. Two or three years ago the fees were again increased to $10 for the first ton and $10 for each additional ton, making $50 for 5-ton trucks. The board, of which I happen to be a member, has submitted a bill to the legislature for passage at its coming session, levying $20 for the first ton, $50 for vehicles carrying between 1 ton and 2 tons, $100 for the 3-ton size, and $150 for the 5-ton truck. Even these fees are not comparable to the damage these trucks do. I told a man in my community who asked to have certain roads improved that a proper fee for his truck would be $1,000 a year, and that even then he would be a burden to the Commonwealth in running that truck. He carried about a 15-ton load every day in the year for the paltry sum of $17 a year.

We might as well meet this problem face to face. I question very much whether we could justify our present low scale of fees if we were called upon. We do not believe that the ordinary individual who comprises the great 99 per cent of the population of our State is called upon to submit to taxation for the benefit of the few. We believe in taxing the motor truck somewhat proportionately to the damage it does, and we feel that until we do we shall be unduly and unfairly laying the burden of these loads on the ordinary individual.

Andrew Marvick, commissioner, South Dakota: I subscribe to the spirit of the remarks of the gentleman from Massachusetts, but in fitting action to the thought I should be inclined to go a little further. I do not think the tax proposed will begin to pay for the damage done by the trucks. In my judgment the tax should be about $50 for the first ton, and it should be greatly increased for every additional ton. We all agree that the heavier loads are the ones that damage the roads. Why not, then, make them pay proportionately, say, at the rate of $100 for a 2-ton truck, $200 for 3 tons, $400 for 4 tons, $800 for 5 tons, and $1,600 for a 6-ton truck. If they build them any larger, we can go up with them. That would be the best solution of the problem.

MARYLAND ELIMINATING OVERLOADING.

J. N. Mackall, chairman, State roads commission, Maryland: We started out with a tax of $25 on a 1-ton truck, $150 on $5 tons, and $500 on a 7-ton truck. Two years ago we found that $500 would not carry a 7-ton truck, nor would $5,000 carry it, so the last legislature provided that no trucks of greater than 5 tons capacity would be licensed.

Then we started out to clear the highways of undesirable overloaded trucks. We could not tax them out of existence, so we decided to legislate them out. One large company was operating a fleet of 107 trucks to Boston from a point beyond our western border. They came in over the national pike to Cumberland, carrying 14,000 pounds net, and the trucks weighed about 6 tons. We fined them $50 for overloading and made them take off the load, put it on the railroad train, and ship it to Boston by rail. They kept on coming. We got $50 a trip, and they kept on coming. That wasn't what we wanted. We established a weighing station

over in the mountains, where the road enters the State. When we caught a truck carrying a gross load of more than 10,000 pounds we made the driver unload and pile his merchandise on the side of the road until another truck could be brought in to put it on. We only had to unload two trucks to convince them we were in earnest. They could afford to pay $50, but when they had to send another truck 17 miles over the mountains to pick up the load and carry it to Boston they quit.

As a result of our experience we consider it is a simple matter to eliminate overloaded traffic. We thought three months ago that it might be very difficult. On our main lines we erected permanent scales, where we can weigh 20 tons. On the other highways we use the loadometer. We have found it very satisfactory except that when they come thick and fast it is difficult to weigh them without a great deal of protest on the part of the truck drivers. During the first week of the campaign, which was the first week in September, we caught 60 trucks on the Washington road. We found the owners guilty of overloading and fined them from $10 to $100. The next week on the Belair road we got 70 trucks; at the end of five weeks we got three trucks in a week; the sixth week we got only one truck. We have not averaged more than one a day for the last three or four months, and it begins to look like we have practically eliminated overloading.

For the purposes of the campaign we have erected two sets of permanent scales—one on the Baltimore-Philadelphia road and one on the Washington Boulevard. We use these one day a week, and supplement them by the use of the loadometer on the other roads where we have knowledge that trucks are operating. When we have no definite knowledge of violations of the law, we simply select a road at random. The uncertainty as to where we are going to be does away with the necessity for constant patrol. The patrolmen all have the power of arrest and do actually arrest, but they also see that the truck is unloaded immediately, and this, we believe, is the salutary part of the treatment.

We believe we have hit upon the solution of the problem. Certainly it is not sufficient merely to increase the license fee, because that does not make it possible to maintain the existing roads. Nor is it enough to arrest the violators of the law and fine them—they are perfectly willing to pay for the privilege of carrying the overload. The only measure which seems to be effective is to unload the trucks.

COOPERATE WITH MANUFACTURERS.

J. N. Cole, commissioner of public works, Massachusetts: There seems to be a very definite purpose in the minds of most of those in control of the operation and construction of highways to force the trucks off the roads or make them pay a fee which will adequately compensate for the damage they do to the highways. I think it will be wise to think twice before accepting the first proposal. It would be wrong to adopt the theory that these roads are sacred for a single individual or for a group of individuals. The theory that should guide us is that roads are for service, and beyond that it seems to me that we are charged to-day with the construction of highways in order that motor trucks may operate over them with a service to the community comparable with and even perhaps more important than the service of the railroads and the waterways. If we overlook that we shall fail to make of the highways the agency to industry, to commercial life, to transportation in its broad relation to world activities, that it must become in order to justify, in the end, the big expenditures we make. The way to solve the problem is to cooperate with the manufacturer of trucks, working along little by little until we reach the point where he knows he can not afford to destroy highways any more than the railroad man can afford to run a 40-ton locomotive on a 40-pound rail. When you reach that point you will have no difficulty.

UNIFORM TRAFFIC LAW WILL HELP.

Clifford Older, chief engineer, Illinois: I think there can be no doubt that load limitations should strike a balance of economy between motor-truck operation and the maintenance of the road surface. Whether we know just what the load limitation may be to strike that balance at the present time is a matter of some doubt. However, all of us here are so intensely interested and have such a knowledge of the damage done by excessive loads that it seems to me that some load limitation at the present time is almost essential. A uniform traffic law might be a possibility. I believe that it is, and as an illustration I would say that the Mississippi Valley Association of State Highway Departments decided a few years ago upon certain load limitations which were thought to be fair for the Mississippi Valley States. Such a uniform law was drafted or the governing provisions of such a law were agreed upon, and a number of our States have followed with the passage of such traffic laws. The Illinois law may be cited as illustrating the general provisions agreed upon. It provides for an 8-ton axle load as a maximum with 800 pounds per inch width of tire in contact with the road surface. We believe that it is better to specify the axle load than the gross load, inasmuch as an investigation of figures submitted by truck manufacturers shows a variation of load on the rear axle of from 57 to 93 per cent.

Modification of Contracts To Meet Present Conditions.

W. R. NEEL, State Highway Engineer of Georgia.

IN presenting for consideration a new form of contract I wish to remove from the minds of everyone any suggestion or thought that I have devised a form of "cost plus" under a new name. However, the "cost-plus" contract when originally drawn embodied two fundamental principles, which were based on fairness to everyone: First, that the owner or beneficiary should pay the cost of the improvement; second, that the contractor effecting the improvement should be fairly compensated for his efforts. Recognizing these two principles, we have had as a result several forms of contracts based on these fundamentals. The plan which provides for the payment of cost with a percentage of whatever that cost might be to cover the compensation, commonly known as the "cost-plus plan," is in bad repute, and certainly the results of the use of this method during the late war have given everyone just cause for prejudice against it. In an effort to remove the incentive to an unscrupulous contractor to increase the cost, thereby increasing his profit, the cost plus a fixed fee was tried out and proved more satisfactory to the owner and also the conscientious contractor.

GEORGIA'S FORM B CONTRACT.

My principal criticism of the "cost-plus fixed-fee plan" is that there is no incentive for the contractor to keep down the cost of the work other than a desire to secure a reputation for economical and efficient work. In public work where it is necessary to advertise and receive bids, thereby removing to a great extent the discretionary powers of the public official in selecting the contractor, something more than is provided in these two forms of contract is needed. In attempting to embody the two fundamental principles recognized by everyone as a basis for any contract, and at the same time perfect a contract more adapted to the execution of public work, the Georgia Form "B" contract was written.

The original draft was submitted to a large number of experienced engineers and contractors and to legal talent and changed to meet the suggestions we thought worthy of consideration. Since initiating work under this form of contract other changes have been made to perfect its weak points, and in submitting it I am cognizant of the fact that it will probably be changed from time to time as experience in its use directs.

In approaching the demand for a new form of contract in Georgia I was confronted with a constantly ascending scale of unit prices, each succeeding set of bids being a little higher than those preceding, until it was a question of either suspending the letting of new contracts or of devising a means of decreasing the cost of the work. I do not wish to place all the blame for the excessively high bidding upon the contractors. They in turn were under the fear and actual conditions of constantly ascending prices for material and labor, together with the uncertainty of freight rates, until no one knew where he stood nor how to bid. It was a gamble, as the old form of contract always has been, with the odds heavily against the contractor, and, as a consequence, there was high bidding. Furthermore, everyone was affected by the many uncertainties, and the bonding companies, realizing the greater risk, demanded of the contractor higher bidding. On several occasions contractors have informed me after the bids had been rejected that they were willing to submit a lower bid but could not secure a bond if they did so.

It therefore appeared to me that in order to meet this situation it would be necessary for the State of Georgia to carry a large part of the risk, and, briefly, the actual use of the present form of contract immediately produced the desired results in decreasing the cost of the work to the State.

HOW THE CONTRACT WORKS.

The use of this form of contract does not eliminate competition. The contractor in submitting his bid divides it into two parts—the estimated cost and the desired compensation. In order to have an incentive to keep down the cost the contractor is allowed 25 per cent of any saving on the estimated cost, provided it does not exceed 50 per cent of the total compensation in the proposal, and should the cost exceed the estimate 50 per cent of this excess is deducted from the compensation, with the provision that the compensation must not be reduced more than 75 per cent. Therefore the contractor is assured of at least 25 per cent of the compensation, as shown in his bid, for which he must furnish at his expense a superintendent and any overhead expense, such as the maintenance of his general office. It is calculated that the 25 per cent will allow the contractor to break even, with no loss other than that of his time. The contract also provides for a machinery and equipment rental, a form being provided which must be filled out and which forms a part of the contract cost of work. However, the rental schedule is fixed, and only the interest on the value of the equipment is allowed, plus a fair compensation for depreciation, insurance, and estimated repairs. In this way no profit can be made other than that shown as compensation, and this amount varies with the skill and zeal used in the prosecution of the work. Thus the minimum compensation obtainable by the contractor will be 25 per cent of the compensation shown in the bid, and the maximum will be the compensation shown

in the bid plus an additional 50 per cent of this amount. If the contractor should be so fortunate as to receive the maximum, the State should not begrudge him this additional compensation, as any additional compensation means a saving of three times as much to the State.

The cost of the work is paid by the State, which is required to pay promptly all bills in order to take advantage of any cash discounts. A bonded accountant in the employ of the State makes up pay rolls and supervises the paying of all labor, etc. All materials are purchased by the purchasing agent of the State highway department, and the prices for all materials, f. o. b. railroad siding, are included in the proposal. In this way the only financing required by the contractor is in purchasing of equipment pertaining to the job and in paying the salary of his superintendent. This has resulted in the immediate delivery of all necessary materials for the vigorous prosecution of the work as soon as practicable after the awarding of the contract.

REDUCED COMPENSATION DEMANDED.

The contractor is called upon to furnish the necessary equipment and a skilled organization properly directed by an experienced and efficient superintendent. The elimination from the requirements of the contractors of practically all financing results in a considerable reduction in the compensation demanded by them, so that this is practically net profit to the State under this form of contract.

At first thought it might appear that the compensation of a contractor could be saved by an organization operated by the highway department, but analysis makes it evident that the item of compensation of a contractor, if conservative, would closely correspond to the operating expenses of an organization owned by the highway department, and, while it should not be the case, I am afraid in actual practice it would be hard to get supervision for a State contract in an organization working on salary that would exert the same effort in construction as would a contractor, under the Form B contract, where incentive in dollars and cents would be to keep the construction cost under the estimate. At the same time the estimate must be conservative in order to meet the competitive feature.

In addition to this objection to a State construction organization there would be the enormous investment in equipment which could only be used on State highway work, whereas a contractor has for a field not only State highways within the State but in other States, as well as municipal, railroad work, etc.

GIVES OPPORTUNITY TO SMALL CONTRACTORS.

One of the first advantages in this new form of contract is that it permits honest contractors of small means to show their ability on a larger scale than would be possible under the old form, under which a surety bond is required for the full amount of the contract, which many contractors of small means are unable to make. At the same time the facilities for financing this Form B contract open a field for intelligent, honest bidders who would otherwise be unable to participate in a project of very great magnitude, except as subcontractors, although their ability might be ample to handle the project.

A striking example of this is a recently completed concrete paving project. The successful bidders could not have financed a project of this extent under the old form of contract, and yet they have had charge of the construction of more miles of concrete pavement within the State than any other contractor. The result has been that 5½ miles of 18-foot concrete pavement were laid in 3¼ months at a 15 per cent net saving on the contract as awarded. The contractors not only earned the compensation set forth in their bid, but an additional 50 per cent, the maximum amount permissible. The advertisement for the letting of this contract, as is our custom, called for bids under both forms of contract. The successful bid was on Form B, and was 24 per cent less than the next lowest bid, which was on the old form contract, and it therefore resulted in an actual net saving of practically 30 per cent under the Form B as against the standard form of contract.

One contract for concrete pavement is showing a saving of 11.3 per cent on first estimate. Federal-aid project No. 162, a grading job, shows a saving of 13.2 per cent, and the work has been under way for more than three months.

The contracts now under way in Georgia under the Form B plan amount to over $1,500,000, and a saving of a little over $20,000 has been effected in bond premiums alone, as a minimum bond is required under this form of contract.

The supervision that is required under the Form B contract by the State requires a very high-class man, preferably one with experience as an inspector on the old form contract, and also experience as a contractor, or superintendent for a contractor. His duties are to watch for violations of the contract and to catch the leakage on the job. The former duty should be performed subconsciously, but most of his thonghts should be centered on methods to reduce the cost. The cost sheet tells him a very true story and should be kept up to date, so that he can see at a glance where he should put most of his attention.

In my judgment this form of contract requires a more intelligent insight into construction details and a more thorough knowledge and analysis of costs by the engineer than the old form.

DISCUSSION OF MR. NEEL'S PAPER.

Frederick S. Greene, State highway commissioner, New York: I can not conceive of any better way to encourage contractors to enter the highway field than by this cost-plus-fee arrangement. Highway contracting seems to be about as big a gamble as there is in the contracting field, and, furthermore, highway contracting as it has been conducted in the past is not a business which the large concerns care to go into. In 1919 several large companies that I know of started into the highway contracting business. I have since talked with officials of three of them with a view to letting large contracts and having two or three plants on the job, and they have told me that they have had enough of it; that they can not compete with the smaller contractor who does not have the overhead that a large concern must necessarily have.

Many States would probably find that legal difficulties stand in the way of putting the plan into effect. Such would be the case at the present time in New York, but in my opinion any State in which the law will permit would benefit by using this form of contract.

PROTECTIVE FEATURES SUGGESTED.

One weakness which occurs to me is the possibility of contractors entering into combination to raise the estimated cost of the job in order to profit on the apparent saving which would be attributed to the efficiency of the contractor. To prevent this the engineer's estimate should be published and it should be understood that no bid would be received which overruns that estimate. It would be well, also, to have the engineer estimate the cost of a suitable plant, so that the contractor could not load down the job with surplus equipment. If, then, the engineer were to fix a reasonable time for the completion of the work and it were understood that plant rental would be paid only for the estimated reasonable period, there would be an added incentive for the contractor to expedite the work.

With these changes made, the only stumbling block I can see lies in the question as to what is to be done when the work overruns the estimated quantities. According to the terms of the contract "any changes in quantities, whether increases or decreases, shall be computed and certified by the engineer at the unit prices quoted therein and the fixed compensation and rental of equipment increased or decreased in proportion." That reads very simply, but I am afraid there would be difficulty in applying it. Take the case of rock excavation, for example; in our State—and I presume in other States as well—we do not go to the expense of making borings to actually locate the rock. To do that would run the cost of surveys up to an enormous price. Really our estimate is merely a careful guess. Of course, it is a guess based upon the experience of men who are familiar with the general lay of the rock. But, in spite of that, rock excavation frequently overruns or underruns, and in that case there is a question in my mind as to how to adjust the item of rock excavation to the general fixed fee. It would seem to me to be a rather difficult proposition. That is the only question that I think is yet unsolved by this form of contract. I would prefer to have the contract written so that the contractor would share equally with the State in any saving he makes; but that, of course, is a matter of personal preference.

PROPOSED FORM WOULD DEVELOP DISPUTES.

W. F. Cocke, assistant commissioner, Virginia: Though I fully realize the difficulties under which contractors have been working for the last three years, and would be glad to see the development of a form of contract which would minimize the unfair risk which contractors are now required to take, yet, at the same time, I think this proposed form of contract may develop a great many indeterminate items, which, under certain conditions, would lead almost inevitably to the courts. Taking care of the percentage of increase and decrease of rock excavation would of itself be a very intricate problem. I have had a good many years' experience on railroad work in the mountains and I have never seen two engineers who could agree as to percentage of solid rock. Another difficulty, which I believe we would encounter in my own State, lies in the fact that this form of contract would afford an opportunity for a great many inexperienced road builders to grasp the opportunity to go into business without a great amount of risk to themselves. I suppose the same condition exists in other States, but we have hundreds of men who have been inspired from their early youth to tell everybody how to build roads, and a great many would flock to the construction game if they could go into it with the element of risk to a large extent removed. If we exhaust the supply of experienced contractors and fall back on this class I fear the public would suffer materially.

WOULD ENCOURAGE SMALL CONTRACTOR.

A. R. Hirst, State highway engineer, Wisconsin: We in Wisconsin have been very much interested in this form of contract which has been proposed by Georgia. One thing in the situation which would deter us somewhat from adopting it is that the contractors have been contending for three years with a rising market. They are now getting the benefit of a falling market, and I know that the moment Wisconsin proposed to change to this form of contract they would accuse us of taking away their chances of recovery.

But I can not agree with the objection which has been raised on the ground that the new form of contract would give encouragement to inexperienced contractors. It is highly essential that we develop contractors, and the only way we can develop them is by

encouraging them. They must be educated and the public will have to pay the bill. The only alternative is the development of large day-labor organizations, which I do not believe we should undertake.

I am heartily in favor of encouraging the small contractor. I believe, as a general proposition, that the States that are going ahead on the basis that highway work requires large organization are making a mistake. An experience of very many years in highway work of all classes indicates that highway work, after all, is a small unit operation, and that a multiplication of those units in one place does not necessarily mean lower costs or increased efficiency.

Frank F. Rogers, State highway commissioner, Michigan: We have had some small experience in this way, but not just exactly in the manner provided for by the proposed contract form. In some cases where we have been unable to get satisfactory bids we have made arrangements with a contractor in whose business ability we had confidence, agreeing with him on an estimated cost of the work and agreeing to pay him cost regardless of whether it ran over or under the estimate. We have further agreed that he should have 50 per cent and the State 50 per cent of all that could be saved on the estimate. Up to date we have made a saving in every case.

Organization of a State Road Maintenance Department.

J. N. MACKALL, Chairman, Maryland State Roads Commission.

THE State highway department of Maryland is probably the only one in the country which does not maintain a maintenance department. Yet it is the belief of the writer that Maryland has at this time one of the most efficiently and satisfactorily maintained systems of highways in the country, and this is accomplished without a maintenance department. In any event, the department is rendering a "road service," which, dollar for dollar, is undoubtedly the cheapest in the country. This economical "road service" is possible partly because the State roads were built when materials and labor were very cheap, and partly because, regardless of how weak the road was in the first instance, it has been and is being maintained to-day in a highly satisfactory state of repair.

WHY A MAINTENANCE DEPARTMENT?

The first question to arise, therefore, is, "Why a maintenance department?" Is there not a tendency to-day toward overorganization rather than underorganization, and is not a State highway department a department of the State government, and is not this carrying departments far enough?

The principal argument which the writer has heard for a maintenance department as separated from the construction department is that, usually, good maintenance men are poor construction men, and vice versa. To his mind no greater fallacy ever existed than this. What makes a man a good construction, maintenance, designing, financing, or even propaganda engineer? Is it not in the final analysis just plain "horse sense," plus experience, and will not the same "horse sense," plus experience, which makes a good maintenance engineer, also make a good combined maintenance and construction engineer? If he exercises good judgment as a construction or as a maintenance engineer, you may be assured that he will use the same good judgment in the combined positions.

Another argument often used is that if maintenance is separated from construction the time, efforts, and enthusiasm are concentrated and not divided. Enthusiasm is, of course, necessary, but actually does not the man immediately in charge of any piece of work supply most of this, so it is not necessary that the head of department or even the subhead have it. The writer's idea is that the judgment should come from the top, the enthusiasm from the bottom.

One of the greatest assets, if not the greatest, which any highway department has is the confidence of the public, and no highway department can continue longer than the public believes it is reasonably efficient and thoroughly honest, and, certainly, willing to listen to reason. If this is true—and we look for the greatest source of danger from this point—where do we find it? In the lack of cooperation, lack of understanding, and lack of appreciation on the part of one or the other of the subdepartments as to what is proper construction and proper maintenance. It is impossible to keep the knowledge of these conditions from getting to the public, and filtering through the public back to the department, and the writer believes that too often this does not come to the department until it comes through the public. Is it not a fact that soon the public comes to believe that both the construction and maintenance departments are right—right in their criticism of the other? Stop criticism in the department and you will stop criticism of the department. On the other hand, if maintenance is going to follow construction immediately and consistently in the hands of the same man he will not say, nor permit anyone else to say, that the construction is not the best; that the alignments, grades, and details of finish are not the best that could be obtained; and any defects which do exist will be corrected as rapidly and as satisfactorily as possible without criticism for their existence. In other words, the defects will be corrected, not criticized.

NOT JUSTIFIED ON ECONOMIC GROUNDS.

There can be no economical lines of demarcation between construction and maintenance; so why have any? Who will say that things are not done in construction which do not return 10 cents on the dollar, when the cost of doing similar work in the form of maintenance is considered? Consider, for instance, the one question of shaping shoulders, sloping banks, etc. This work, done by the contractor, usually by hand, at a tremendous expense, is obliterated after the first rain. After this it is done with a road machine at probably less than 10 per cent of the cost of the contractor's handwork; yet who has ever seen a construction engineer willing to accept from a contractor a piece of road unless the shoulders and slopes from beginning to end were in perfect state of repair on the day of acceptance, regardless of whether or not this would last for one day or one week after the road is actually accepted? The writer does not want to be understood as unfavorable to reasonably well-shaped shoulders and slopes, but they should not be done better than they can be maintained. Make no mistake, the ultimate consumer, the public, pays all the contractor's bills and a profit on them. How, then, are many of the economic problems involving construction and maintenance going to be solved except from an intimate knowledge of both, and how is this to be had when the two departments are kept separate? It can not be done. What is to be done as construction or left undone to be taken up as maintenance can only be determined by an intimate correlation of the two.

If it is remembered that the money, whether used for construction or maintenance, is the public's money, and that the public is interested not at all in whether the work for which its money is spent is named construction or maintenance, but only in seeing that it receives 100 cents for each dollar expended, the separate construction and maintenance departments will disappear. This seems to the writer, generally, a reason for not maintaining a maintenance department separate from the construction department, and up to this point nothing tangible and definite in the line of saving of money has been touched upon.

SAVING OVERHEAD AND TRAVELING EXPENSE.

The writer believes, moreover, that a large proportion of the overhead and traveling expenses can be eliminated by combining the construction and maintenance departments, and that much duplication must and does exist where these departments are separate. The State of Maryland, for example, has constructed probably as many of its main through roads as any State in the Union. It has connected by an improved road every county seat in the State, and, in addition, every town of more than 1,000 people is connected with every other town of similar or larger size by an improved road maintained in almost perfect condition. Certainly, then, it would have less duplication of overhead and traveling expense than the States which have not completed their main line system, yet, even in Maryland, construction and maintenance go together so closely that it is impossible to inspect and supervise construction without at the same time going over maintenance and vice versa. In States where the main line systems are not completed, and where construction sections immediately adjoin maintenance sections, it is evident that expense can be saved by combining the departments, but it is equally true where the main lines are completed, because new construction on the branch lines immediately joins the main-line maintenance. The writer has reference only to connected systems and it is assumed that all departments are organized with hope and expectation of eventually having a connected system, if not now. Certainly, then, separate construction and maintenance departments make for duplication of effort which can only mean duplication of expense.

AS TO RECONSTRUCTION WORK.

Probably one of the most potent factors in arriving at the combined construction and maintenance department is the feature of reconstruction. "Reconstruction" is a word which probably should never have had a place in highway work. The work called reconstruction is really maintenance, and the cost of it should be charged against current receipts. Under a system of separate maintenance and construction organizations how is this reconstruction to be handled? By reconstruction the speaker means extensive reconstruction, essentially new construction, done by contract. For instance, why should the building of a sheet-asphalt top on an old macadam or concrete base be under the maintenance department and another section in the immediate vicinity, built on the identical specifications but on a new base, be under the construction department?

To pursue the contrast further, take as an illustration the work Maryland has just done on a 50-mile section from Washington to Baltimore and on to Belair on the road to Philadelphia. This consisted in a few cases of replacing the 14-foot macadam with 20 feet of concrete. But in most cases it consisted of the construction of a strip of concrete 3 feet wide on each side of the macadam, as was fully described in the September issue of Public Roads, which, no doubt, some of you have read. Under Maryland's system of financing, then, the work done on the 14-foot width of macadam was charged to maintenance and the additional width of 6 feet to construction. With separate construction and maintenance organizations would all this work be done by the construction or the maintenance department, or would each one have done its portion of the work? This may be an extreme case, but it demonstrates conclusively that maintenance and construction are inseparable in execution. So why maintain separate organizations?

Having advanced the reasons leading up to the organization of construction and maintenance work along similar lines, and having referred to the saving in overhead in connection therewith, the writer will perhaps be pardoned for citing the organization he is now maintaining as an example of the kind of organization which in his judgment will give the best results in both construction and maintenance.

THE MARYLAND ORGANIZATION.

The State roads commission of Maryland as at present constituted consists of three members, of whom one is the chairman, and the law provides for a chief engineer and assistants. The commission, in organizing, selected the chairman as chief engineer, so that the authority and responsibility is concentrated at the top as much as possible. Under the chief engineer is an assistant chief engineer, who has such duties as are specifically entrusted to him by the chief pertaining to all phases of the work, including surveys, plans, construction, maintenance, and costs. In all his dealings he acts for the chief engineer and in his stead, so that all reports to him have the force of reports to the chief engineer. Next in line of authority is the district engineer, there being seven of these in charge of the work in Baltimore city and 23 counties of the State, averaging a little more than 3 counties to a district. The district engineer, therefore, is really the first subdivision lower than the chief engineer, there being neither construction nor maintenance engineers in the department, and the district engineer, therefore, handles and is responsible for both construction and maintenance in his district.

The maintenance work is further divided, approximately by counties, with a superintendent for each county. The maintenance superintendents and construction inspectors are interchangeable, so that it is possible to fill the position of district engineer from within the ranks of the organization. The purchasing agent, working directly under the chief engineer, is responsible for the purchase and delivery of all materials. The materials as required by the district engineer are requisitioned from the purchasing agent with specifications as to quality, time, and point of delivery. Centralized purchasing has always been desirable in that it stops competition for price and delivery within the department, but the difficulties in obtaining materials and in their transportation during the last few years have demonstrated the absolute necessity for it.

All requisitions are forwarded by the district engineer to the chief engineer for approval and order of delivery, and then transmitted to the purchasing agent, who places the order and effects delivery to the point of destination on the railroad or water, from which point the responsibility for ultimate delivery is with the district engineer.

MAINTENANCE BY PATROL SYSTEM.

Maintenance, other than extensive reconstruction done by contract, is effected by the patrol system, supplemented by the gang system. The backbone of the maintenance system, however, is the patrolman, the man with the pick and shovel. It is the writer's opinion that no road can be properly maintained without the patrol system, regardless of whatever else may be used. Properly maintained, as it is interpreted in Maryland, is perfectly maintained, so far as the surface is concerned. No hole of the smallest size is permitted to remain in any highway. By this system the department is rendering a most satisfactory road service on very low types of construction, and at a most reasonable figure when interest and maintenance charges are considered. It is, of course, necessary at times during the year, especially in the spring, to supplement the patrolman with a gang, which does small sections of resurfacing, cleaning of ditches and culverts, dragging shoulders, etc.: but the gang does not relieve the patrolman: it only supplements him. The gangs are under the direct supervision of the foreman in charge, but report to the maintenance superintendent in the district and he, in turn, to the district engineer. The gang is entirely independent of the patrolman, though the latter is at times employed in the gang.

On numerous occasions it has been attempted to dispense with the services of the patrolman, but invariably it is found to be impossible properly to maintain the roads. One of the greatest difficulties with patrol maintenance is that the patrolman frequently works inefficiently. We have found it expedient to overlook a certain amount of loafing, which we recognize as inevitable, because we hold firmly to the belief that the patrol system, in spite of the inefficiency of individual patrolmen, is a necessary adjunct to perfect maintenance. Whenever the services of the patrolman have been dispensed with, public-spirited citizens, true friends of the road movement in Maryland, have noticed that this has been done, and have noticed that the roads were not being maintained in their usual first-class condition.

The speaker believes that there is as little loafing and unintelligent work done by the patrolmen in Maryland as any State in the Union. This, he believes, is largely due to the fact that whenever inspections are made, either of construction or maintenance work, the patrolman comes under the eye of the inspecting officer, who is in authority on maintenance work.

SINGLE DEPARTMENT MOST EFFICIENT.

In conclusion, the organization of a combined construction and maintenance department prevents the dodging of responsibility. It concentrates in the hands of the district engineer undivided authority and undi-

vided responsibility for the building of good roads, and maintaining them in perfect condition. It stops criticisms of bad construction, of bad maintenance, of things done and things left undone. It makes for a coherent absolutely loyal organization, free from the faultfinding and backbiting which results chiefly from the conflict of separate construction and maintenance organizations.

Efficiency is certainly the keystone in any organization. Combined construction and maintenance organization makes for efficiency of funds in that a dollar does a dollar's worth of work; efficiency of men, in that one man does what two would do otherwise; efficiency of results as reflected in Maryland's 1,600 miles of roads maintained in perfect condition in 1920 for an average of $600 per mile.

DISCUSSION OF MR. MACKALL'S PAPER.

J. H. Mullen, chief engineer, Minnesota: I can not agree with the argument that there should be no State highway maintenance department. It is undoubtedly true that in a small State, having only 1,600 miles of arterial roads, of which practically all have been surfaced, the maintenance and construction work can be handled efficiently without separation. But these conditions do not prevail in many of the States, and for the reason that we do have such various governing conditions in the several States, it would be very difficult, if not entirely impractical, to set forth a standard method of organization applicable to all.

The organization of a State highway maintenance department is one of several highway problems which must be studied and worked out largely with reference to local conditions. Take, for instance, the organization in Maryland, which is described as being ideal, and upon analysis it would appear that this State highway department is really in effect a maintenance organization, and the small amount of construction necessary under the stated conditions could properly be considered as incidental work, the same as grade separations, material surveys, or other subactivities are considered as being incidental to the maintenance and construction departments in other States.

I do not wish to be understood as criticizing the Maryland organization. On the contrary, I have no doubt that it is the most effective that could be worked out to handle the local problem, which appears to be largely maintenance. But if that State should enter upon an extensive construction program I think it might be found advantageous to provide for a construction department within the organization.

ONE DEPARTMENT, SEPARATE DIVISIONS.

Having departments of construction and maintenance does not mean complete separate organizations. They are both integral parts of the highway department but are each in charge of men specializing in the particular branches of the work. I have received the greatest help in conducting the work in our department by having as principal assistants three experts, one in charge of road construction, one bridge construction, and one maintenance. These men sit in conference with me on all questions of specifications, engineering policy, or methods of work, acting really as an engineering council, and bringing out the best ideas with regard to all phases of the work. Under this plan there is no danger of domination by one branch of the work to the detriment of another, as might be when there is no separation. I have not found that this method leads to any dodging of responsibility or "backbiting," as described, for the engineers in charge of the three different branches are interested and feel a sense of responsibility for all of the work. However, if such a condition as mentioned should arise, it would be the duty of the chief engineer to institute a house cleaning.

EFFICIENCY BY SPECIALIZING.

The great advantage of having a maintenance department is in the efficiency brought about by specializing, a point which needs no elaboration in this meeting. This, however, has been demonstrated by experience in the Middle West, where for the last 5 or 10 years the States have been engaged in the construction of from 500 to 2,000 miles of new work each year, and also the maintenance of from 400 to 12,000 miles of all kinds of roads, ranging from common bladed dirt roads to the highest types of pavement. This is particularly true in Minnesota, the first State in the Mississippi Valley to consider maintenance as a State activity.

I believe considerable credit for starting this work should be given to Mr. George W. Cooley, former State engineer of Minnesota, whom most of you know as a fine gentleman and a good roads pioneer. Twelve years ago the State highway commission, of which Mr C. M. Babcock was then chairman, ordered Mr. Cooley to investigate road conditions in Europe, with a view to applying the results of the investigation to construction of roads in Minnesota. Mr. Cooley spent a year in this investigation and upon his return made a report to the commission that the desirable road conditions generally prevailing in Europe at that time were not due to construction methods but rather to an intensive system of patrol maintenance. Consequently there was established under Mr. Cooley's direction a patrol system of maintenance in Minnesota which has continued since that time quite successfully under various methods of supervision, and, I am pleased to say, has been adopted in several of our neighboring States.

The management of the work has been conducted in various ways since the State took charge. First, it was considered as a county proposition, then as a part of the miscellaneous work of the department, and during

the last four years as a separate subdivision of the work. And now, in the light of our experience, we are satisfied that the latter method is most productive of results. As stated before, this does not mean complete separation but only a division within the highway department.

RESPONSIBILITY DEFINITELY PLACED.

It seems to me that responsibility for each general branch of work should be definitely placed in a subdivision of the highway department charged with responsibility for doing that particular work and given the authority to carry it on. Minnesota has just passed a constitutional amendment selecting from the 12,000-mile State road system a trunk highway system 7,000 miles in extent. The trunk highways will be maintained directly by the State and the remaining State roads will be maintained by the counties under direction of the State with State aid. Under this plan our work will be in charge of a maintenance engineer reporting directly to the chief engineer and working in conference with the construction and bridge engineers. His department will also have in charge such matters as grade-crossing separations, rights of way, traffic census, etc.

The State is divided into eight divisions, each having a division engineer who has control of all work in his territory and who will have as his principal assistant an engineer known as the road superintendent, whose duty it is to give personal direct supervision to the maintenance of the trunk highways. The construction work will be handled as before by resident engineers reporting directly to the division engineer. The road superintendent will have authority to employ such men and equipment as may be required to carry on the work and will have use of the excess war trucks and tractors now being employed for this purpose to very good advantage. We have made it a policy not to purchase any considerable quantity of small tools, but to engage individuals at a stated rate including the use of tools, teams, wagons, etc. Heavier equipment, such as graders, tractors, tarring equipment, etc., is, of course, furnished by the State, excepting where the equipment of a county is employed on a daily rental basis.

MAINTENANCE IS DAY-LABOR WORK.

An outstanding difference in the construction and maintenance organizations is that the first is a contract organization, for we believe in contracting for all construction which can be figured on a unit basis, while the maintenance organization is almost entirely a hired force and does all miscellaneous day-labor work.

The maintenance work in our State amounts to a great deal more than the name implies. We do not consider that maintenance is successful unless it brings about a substantial betterment of the road, and we class as maintenance all those minor improvements, such as shoulder surfacing, light regraveling, reshaping of roadway on earth roads, and even grading with blade graders to natural contour those connecting roads which do not for the time being require construction. It is also the duty of the maintenance department to mark the trunk highways and to mark and maintain suitable detours around construction work. In short, it is the duty of the maintenance department to see to it that traffic is maintained continuously over the highways in the most satisfactory, efficient, and economical way, which, in my judgment, requires direction by men who are specialists in that work and are not likely to become sidetracked on account of other activities.

Report of Committee on Use and Care of Federal Equipment.

IN developing a report on this subject the committee agreed—first, that the report should quite properly go beyond the limits imposed by its title and include reference to the receipt or acceptance of Federal equipment; and, second, that the report would be prepared and submitted without recourse to a second questionnaire.

The data compiled as of February 1, 1919, are perhaps of questionable value to-day. In each of those States represented by members of this committee, for instance, the year's experience has indicated many weaknesses of policies previously tentatively adopted; has impressed certain fundamentals that will be herein referred to, but has notwithstanding failed to eliminate all uncertainty as to the best method of disposing of this question. The older departments were able to meet the situation brought about by the allotment of Federal equipment with somewhat less confusion than were many of the newer organizations: but it is significant that even among the established organizations no uniform policy obtains. The first conclusion of this committee, therefore, is this: The acceptance, use, and care of Federal equipment is a matter primarily of local concern: the problem is one not susceptible of a single, uniform solution throughout the several States.

ACCEPTANCE OF FEDERAL EQUIPMENT.

This committee believes that too few of the States have asked seriously the question, Shall Federal equipment be accepted, and if so, for what use or distribution? The exigencies of the occasion seemed to justify the haste with which allotments and shipments were handled by the bureau. But the enthusiasm of the moment engendered by the altogether human desire to get something for nothing has, in some instances, we

believe, obscured the economics of the transaction. The result seems to be:

(*a*) Some States now have a surplus of one or more kinds of equipment or materials, both desirable and usable, and a deficiency of other kinds;

(*b*) Some States have a supply of equipment and material wholly unsuited to their needs and requirements, although in itself valuable and serviceable;

(*c*) Many States have on hand material and equipment supplies that, because of its unfit condition or the lack of adequate funds for repair, or both, are altogether valueless to the States.

The transfer of equipment between States might appear to offer a solution of this difficulty, and did at first so appear to this committee. But such transfer is subject to the limitation of distance and is contingent upon agreement between the parties as to reimbursement for amounts invested. This committee believes that the transfer plan is not possible of broad application as long as the State seeking the equipment feels that it may be obtained direct from the bureau at a cost considerably less than that involved in transfer expense plus reimbursement to the State transferring. The points here suggested are:

(*a*) The acceptance of miscellaneous equipment has placed a heavy financial burden upon many States; and

(*b*) Amounts paid out (in freight, etc.) for unusable or undistributable equipment are likely to represent an actual and serious loss to the States.

This committee, therefore, suggests the following:

(1) That each State that has not already done so undertake an immediate determination of its present and future equipment requirements. Such determination involves a decision as to (*a*) ability and plan to finance the handling, and (*b*) plan of use or redistribution.

(2) That each State that has not done so inventory its present stock, segregating the desirable and usable from the undesirable or unfit.

(3) That the bureau endeavor to ascertain and announce the kind, quantity, condition, and value of surplus materials yet to be allotted.

(4) That initial or additional shipments be accepted by the States only when the units can be put to economical use, in accordance with the principles herein noted, within a reasonable time.

(5) That all undesirable or unfit units or supplies be disposed of by the States in whatever legal manner offers the greatest possibility of reimbursement.

(6) That the bureau recognize the reasonableness of the plan of ultimate disposal by the States, as "unserviceable materials," of such units or supplies as may for any reason be unusable or unsuited for the purposes of the State and not possible of redistribution within or without the State. Decision as to the "unserviceability" of units may be reached by agreement between representatives of the State and bureau.

USE OF THE EQUIPMENT.

Acceptance of Federal equipment should be in conformity with a definite policy as to use. If there is no present or immediate future use for the unit its acceptance undoubtedly represents unnecessary expense. This principle apparently has not been recognized by all the States. The possibilities as to use include:

(*a*) Use by the State on day-labor construction or maintenance.

(*b*) Use by contractors engaged in State or other highway work.

(*c*) Use by counties or other civil subdivisions of the State on construction or maintenance.

This committee suggests that—

(1) Wherever possible, the use of Federal equipment should be confined to State forces; and that when so used a proper charge should be made for depreciation so as to perpetuate the life of the unit.

(2) Use of Federal equipment by counties or other civil subdivisions of the State is less likely to lead to friction and disagreement when such use is on a basis of perpetual lease for which a lump-sum payment is made upon receipt of the unit by the lessee. The payment mentioned should very properly be sufficient to cover: Initial cost, if any; freight; loading, unloading, and reloading; hoist, body, and other accessories; overhauling and repair, including supplies furnished; plus a charge to cover overhead and manticipated Federal claims. The perpetuation of equipment leased to counties and cities is believed to be desirable but generally impossible.

(3) Use by contractors should be confined to those engaged in State work unless distribution to other contractors is advantageous to the State in recovering funds. The use of trucks, tractors, and similar equipment by contractors should generally be on a monthly rental basis, determined so as to provide a depreciation fund, insure repair and maintenance, and protect the State against loss. The use of certain types of equipment or supplies not in general demand may be by perpetual lease under the terms of which the State receives a lump-sum payment in whatever amount is agreed upon, or at the price submitted by the high bidder following a request for "proposals for use."

CARE OF THE EQUIPMENT.

"Care" includes handling, storage, housing, maintenance, and supervision. This committee suggests that—

(1) Adequate provision should be made for housing all units found to be usable, pending use or distribution by the State.

(2) If justified by the kind and number of units, permanent repair quarters should be established and maintained with sufficient floor and storage space and sufficient shop equipment to care for the anticipated number of units. This involves policy as to (*a*) returning units to a central depot for repair, or (*b*) repairing at the location of use. Since, however, it is presumed that a central receiving depot will be necessary, it appears desirable to maintain a permanent shop at such location.

(3) Spare parts, small accessories, and supplies should be inventoried and stocked in bins or other convenient containers, listed and readily accessible.

(4) Equipment under "perpetual lease" should be subject to only such supervision by the State as may be agreed to, giving due consideration to cost and expediency.

(5) Equipment rented to contractors on a monthly basis should be subject to supervision by the State,

and all repairs should be made by or under the supervision of the State.

(6) Replacement of parts from State stock should be at prevailing market price for such parts.

(7) Accurate records of distribution and of handling and operating costs should be maintained.

(8) Whenever the volume of equipment business justifies such policy, a separate mechanical division should be established, with appropriate responsibility for use and care.

(9) All agreements or understandings as to use and care of equipment rented or leased should be in writing.

CONCLUSION.

Obviously the details involved in this subject are so numerous as to permit of endless discussion and the preparation of a most voluminous report. One State is interested in the matter of housing, storage, and repair in all the possible subdivisions of the subject. Another is concerned with the organization of a mechanical department, and still another with a determination of rental rates. This committee recognizes the futility of attempting a discussion of and recommendations regarding the many phases of the matter. It may be safely assumed that individual departments are able to develop detailed plans for the conduct of this activity. This committee, then, offers in conclusion the following brief summary of principles and recommendations, the observance of which it is believed will lead more readily to workable details of operations:

(1) Acceptance of initial or additional shipments of Federal equipment should be contingent upon a predetermined policy of financing and upon known requirements of State use or possibilities of redistribution. Acceptance of equipment for other than State use should be, preferably, by previous requisition of proposed user. Uncertainty as to ultimate disposal of units and recovery of funds invested should be eliminated in so far as thoughtful planning can effect such elimination. The amounts charged for rental or lease are purely of local determination. "Perpetual lease" agreements may properly consider matters of altogether local expediency.

(2) Unusable equipment on hand should be promptly disposed of to the best advantage.

(3) The use of Federal equipment by other than the State is very likely to lead to friction and loss. When use is by civil subdivisions of the State the "perpetual lease" plan appears to be most satisfactory; but annual or other deferred payment plans are of questionable value. All rental and lease agreements must be definite as to terms and provisions regulating, to whatever extent is agreed upon, the use and care.

(4) Responsibility for the care of Federal equipment must generally be assumed by the State, except in cases of perpetual lease, when the agreed extent of responsibility may be assumed by the lessee. Efforts to perpetuate the life of leased equipment represent commendable recognition of accepted business conduct, but may lead to friction and embarrassment. Such a policy must be weighed against local conditions and possibilities.

(5) The management of this division of work should follow usual good management procedure, with definite policies, plans, supervision, and records.

(6) The bureau should exercise only such supervision of equipment allotted as is required by law.

Respectfully submitted.

JOHN N. EDY,
ROLLEN J. WINDROW,
For Committee on Use and Care of Federal Equipment.

WASHINGTON, D. C.,
December 13, 1920.

DISCUSSION OF THE REPORT.

R. J. Windrow, State highway engineer, Texas: The report was prepared by the chairman after some correspondence with the other members of the committee. There is only one point I wish to stress, and that is that we must evolve some plan for disposing of the equipment that has been received by the States which is either in unserviceable condition or unsuited for the particular needs of the States. It seems that no definite policy has been evolved for handling that problem. We have discussed it by correspondence, and it seems the law is not entirely clear, but in my opinion we have enough leeway under the present law to dispose of that equipment so we can reimburse the States for the expense to which they have been put in securing it. In Texas we have received quite a large amount of equipment that, from the description we had in advance, appeared to us would be serviceable. Some of it was found upon receipt to be entirely unserviceable for our particular needs. Some of it was received in unserviceable condition. We have a large amount of such equipment on hand for which we have paid freight, loading, and storage charges, and it is necessary for us to be reimbursed for that expense in some way.

DISPOSAL OF THE EQUIPMENT.

Thos. H. MacDonald, chief, Bureau of Public Roads: We have had frequent inquiries from the States as to the policy of the bureau with reference to disposal of this equipment. The only policy that can be enunciated is that of following the law providing for the distribution of this material, which makes it very clear that no material in serviceable condition can be sold. The disposal of the material can not be authorized by the bureau, but should be carried out under the State laws governing the disposal of public property of any other kind. The title of the equipment after it has been delivered rests in the States, not in the Federal bureau.

There is, of course, the question of good faith. The War Department has insisted, in turning over this equipment, that it should be used for road-building purposes. Representations have been made to the committees of Congress which passed the legislation that it would be so used. The only question which has been raised by the bureau with any State, so far as I know, has been to ask for information where the disposal of

equipment has been brought to our attention, either through the agencies of the War Department or through the Department of Justice. Such inquiries have probably been initiated by manufacturers of the equipment or manufacturers of similar equipment who had expected to make sales that were not made because of the disposal of such equipment by the States. In order that we may be able to answer such questions intelligently and honestly, we have requested that complete records of all property disposals be kept by the States.

In general we have taken the position that the title to the property distributed rests in the States; that disposal of it should be made under the State laws governing the disposal of any other State property, and that a clear statement should appear on the records of the commission or the department as to the procedure followed in making the sale or declaring the equipment unserviceable. So long as we adhere to this policy and keep faith with the Congress which made available this equipment; so long as the equipment we dispose of is actually unserviceable I can seen no reason why there should be any question raised; but if any bad faith is manifested, there might be considerable criticism.

As a guide in determining whether a particular piece of equipment may be regarded as unserviceable, I may add that the War Department defines as "unserviceable" any equipment upon which it would be necessary to expend more than 30 per cent of the cost price to put it in operating condition. The Solicitor of the Department of Agriculture has broadened this definition, in his interpretation, to include as "unserviceable" equipment which is unsuited to the road-building requirements of the State departments.

M. L. Shade, commissioner, South Dakota: I have been informed by those in a position to know that there is a large number of trucks and tractors yet to be declared surplus and probably a large amount of other machinery. As a word of caution, it occurs to me, therefore, that if we proceed to dispose of the equipment which is not useful or serviceable to us and the manufacturers make a concerted complaint about it, we might be prevented from receiving any additional equipment that is available or that will be available in the next few months, and thereby lose more than we would by accepting the unserviceable equipment.

A. R. Hirst, State highway engineer, Wisconsin: We are finding in Wisconsin that another word of caution is necessary. We were entitled to receive about 500 trucks. We intended to save 200 of them for our own use with the idea that we would charge enough for their use by contractors on our own work to cover the depreciation and repairs, so that at the end of their use we would be able to buy 200 additional trucks. We have been operating under such a plan for a year and a half, and as a result we found about a month ago that we have not only not collected enough rental to cover the depreciation, but that we actually have not enough to place the trucks in condition for next year's use. And we find ourselves in this condition despite the fact that our rentals have been as high as any State would charge. As a matter of fact, we have reached the stage where our mechanical man says he will not furnish trucks to the contractors and the contractors say they will not have them.

Especially in the Northern States, where work is closed down four or five or six months of the year, I doubt whether the trucks can be rented for enough to really depreciate them, and I am just interjecting this as a word of caution to the States that are planning to rent the trucks.

TRUCKS HAVE PROVED VALUABLE.

Clifford Older, chief highway engineer, Illinois: Our experience has been somewhat at variance with that of Wisconsin. We have received a large supply of equipment, and in the main it has been serviceable and has been kept in useful service by the State. Up to the present time the value received from the use of the trucks and other equipment has not only provided sufficient funds to keep the equipment in repair but to yield some surplus, not sufficient to depreciate the material entirely, but sufficient to keep it in service. I feel that although the equipment may not be put to such service as to provide a revenue sufficient to maintain an equal amount of equipment for an indefinite period, yet we are serving a very useful purpose in getting as much value out of it as possible, considering the character of the equipment. To state that this is not possible with the trucks is equivalent to stating that a truck is not a useful piece of machinery on the highway, or that it is impossible for us to administer the use of the equipment in a useful manner. We have succeeded, as I have said, in actually renting these trucks for enough, which is either paid in cash to our department or in the way of deductions from contract prices, to pay for the freight, unloading, and handling of all the equipment received, and in addition to put up our building, which, of course, should not be charged entirely to the rentals received to date, and still we have a surplus.

As to the adaptation of the equipment that is received in serviceable mechanical condition, but is not useful in the work of the particular State by which it is received, it seems to me we should give a thorough trial to the plan of exchange before deciding to dispose of the equipment by sale, and thus possibly raise some question with the War Department. We have received some equipment that we would perhaps have refused as unserviceable if we had had a complete description of it. However, all such equipment that we have listed with the Bureau of Public Roads for exchange has been exchanged. We now have some additional equipment that we do not believe we can use, but we are in correspondence with the bureau and believe that can be exchanged for an equal value of equipment that is not in service in the State where first received, but which we can use to good advantage. I believe we can go a long way toward the disposal of that class of equipment through the bureau as a clearing house.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN DECEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Ala.	20	Clay	14.700	Gravel	Dec. 13	[1] $342,070.71	[1] $171,035.35
	71	Dallas	[2] .056	Asphaltic concrete.	Dec. 7	[1] 108,340.82	[1] 54,170.41
	94	Wilcox	12.380	Gravel	Dec. 4	284,698.57	142,349.28
	95	Tusealoosa	25.220	...do	Dec. 13	545,545.88	272,772.94
	96	Escambia	20.520	...do	...do	359,706.87	179,853.43
Ariz.	22	Navajo	2.730	...do	...do	15,958.80	7,979.40
Ark.	23	Jackson	3.190	...do	Dec. 16	[1] 36,107.10	[1] 20,000.00
	55	Prairie	1.740	Gravel, surface treated.	Dec. 24	[1] 25,184.73	[1] 16,000.00
	116	Pulaski	2.330	Bituminous	Dec. 17	48,274.49	21,000.00
	124	Craighead	7.690	Macadam	Dec. 16	75,622.40	25,000.00
Colo.	87	Boulder	1.334	Concrete	Dec. 13	57,587.38	26,680.00
	185	Garfield	1.270	Earth	Dec. 16	64,965.72	25,400.00
Fla.	31	Hamilton	11.861	Bituminous macadam.	Dec. 22	458,129.11	229,064.55
Ga.	187	Rabun		Bridge	Dec. 4	95,531.42	28,659.42
	205	Effingham	4.218	Sand-clay	...do	31,213.60	10,000.00
	208	Terrell	8.000	...do	Dec. 13	55,037.62	22,500.00
Kans.	74	Chase	8.620	Earth	Dec. 16	68,687.03	25,860.00
	75	Diekinson	.500	Concrete	Dec. 18	23,399.20	7,500.00
Md.	41	Garrett	1.990	Earth	Dec. 24	44,137.50	22,068.75
	43	Prince George.	.500	Asphalt	Dec. 4	22,068.75	10,000.00
	44	Kent	.950	Concrete	Dec 24	39,138.00	19,000.00
	45	Baltimore	2.040	Earth	...do	30,030.00	15,015.00
	46	Somerset	.710	...do	...do	21,037.50	10,518.75
	47	St. Mary's	1.440	Gravel	...do	86,850.50	43,425.25
Mich.	55	Berrien	2.847	Concrete	Dec. 13	125,756.67	56,940.00
	50	Monroe	13.034	...do	Dec. 22	688,719.35	260,680.00
Minn.	173	Dodge	3.980	Gravel	Dec. 13	44,326.70	5,000.00
	177	Ramsey	2.500	Bituminous concrete.	Dec. 31	159,544.71	50,000.00
Miss.	90	Benton	27.700	Earth	Dec. 22	258,898.75	120,000.00
Mo.	166	Vernon		Bridge	Dec. 7	22,000.00	11,000.00
	167	Bates	14.200	Chat	Dec. 16	280,066.60	140,033.30
	168	Jasper	6.000	Gravel	Dec. 22	31,200.00	15,600.00
	169	...do	7.000	...do	Dec. 22	29,400.00	14,700.00
	176	Pulaski		Bridge	Dec. 13	34,375.00	17,187.50
N. Mex.	60	San Miguel.	21.700	Gravel	Dec. 7	108,055.20	54,027.60
N. Y.	91	Hamilton	8.000	Bituminous macadam.	Dec. 13	320,000.00	160,000.00
	93	Genesee	4.900	Concrete	Dec. 8	279,300.00	97,755.00
	95	Hamilton	27.600	Bituminous	Dec. 13	1,104,000.00	522,000.00
	96	Genesee	9.300	Reinforced concrete.	Dec. 6	530,100.00	185,535.00
	98	Steuben	8.500	...do	...do	484,500.00	169,575.00
	100	Chautauqua.	3.100	Concrete	Dec. 13	124,000.00	62,000.00
	101	Schuyler	3.400	Reinforced concrete.	Dec. 22	193,800.00	67,830.00
N. Y.	102	Chemung and Tioga.	7.800	Reinforced concrete.	Dec. 22	$444,600.00	$155,610.00
	104	Tompkins and Cayuga.	11.100	...do	...do	444,000.00	222,000.00
	105	Wyoming	9.500	Concrete	Dec. 13	541,500.00	189,525.00
N. Dak.	111	Bottineau		Bridge	Dec. 16	16,500.00	8,250.00
	113	La Moure	8.000	Earth	Dec. 13	36,960.00	18,480.00
	118	Mountrail	11.000	...do	...do	50,820.00	25,410.00
	122	Ransom	10.000	...do	...do	44,990.00	22,495.00
	132	Mountrail	6.000	...do	Dec. 31	37,950.00	18,975.00
	133	...do	12.000	...do	...do	55,440.00	27,720.00
	134	Williams	2.500	...do	Dec. 22	18,425.00	9,212.50
Ohio	107	Warren	[3] 6.865	Bituminous macadam.	Dec. 28	[3] 187,000.00	[3] 93,500.00
	111	Delaware	[3] 7.420	Concrete	Dec. 16	[3] 312,000.00	[3] 60,000.00
	143	Logan	[3] 5.600	...do	...do	[3] 248,000.00	[3] 85,000.00
	152	Coshocton	[3] 4.043	...do	...do	[3] 192,000.00	[3] 57,000.00
	190	Madison	9.994	Kentucky rock asphalt.	Dec. 22	328,500.00	150,000.00
Okla.	39	Carter	16.000	Gravel, surface treated.	Dec. 20	340,000.00	170,000.00
Oreg.	48	Harney	10.460	Macadam	Dec. 16	171,192.34	75,596.17
Pa.	88	Indiana	2.688	Concrete	...do	241,760.13	53,760.00
S. C.	91	Kershaw	8.875	Sand-clay	Dec. 22	76,145.86	38,072.93
S. Dak.	67	Clay	13.040	Earth	Dec. 24	87,725.00	43,862.50
	68	Charles Mix.	4.300	Gravel	...do	39,792.50	19,896.25
Tex.	121	Grayson	7.370	...do	Dec. 16	101,938.06	33,333.34
	122	Hill	9.900	...do	Dec. 24	138,015.08	30,000.00
	178	Hays	16.790	...do	...do	101,534.60	30,000.00
	219	Valverde	5.250	...do	Dec. 16	203,398.14	101,699.07
	222	Milam	18.860	...do	Dec. 13	124,564.00	62,282.00
	225	Trinity	17.800	...do	Dec. 16	200,915.55	50,000.00
	226	Jeff Davis	7.216	Earth	Dec. 4	23,981.93	11,990.82
	228	Johnson	12.000	Gravel, bituminous surface.	...do	333,953.18	100,000.00
	229	Tom Green	4.000	Bituminous surface.	...do	112,697.86	56,348.93
Utah.	15	Iron		Gravel	Dec. 22	[4] 147,853.20	[4] 73,926.60
	17	Juab and Millard.		...do		[4] 110,880.00	[4] 55,440.00
Wash.	81	Skamania and Klickitat.	.170	Earth	Dec. 18	47,520.00	3,400.00
	82	Kittitas	1.280	...do	Dec. 24	63,487.38	25,600.00
W. Va.	105	Jackson	.990	Concrete	Dec. 11	28,700.00	14,350.00

[1] Revised statement. Amounts given are increases over those in the original statement.
[2] Revised statement. Amounts given are decreases from those in the original statement.
[3] Withdrawn.
[4] Decrease in mileage.

PROJECT AGREEMENTS EXECUTED IN DECEMBER, 1920.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Ariz.	23	Pinal		Gravel	Nov. 20	[1] $20,916.55	[1] $10,458.28
Ark.	17	Craighead		Water-bound macadam.	Nov. 30	[1] 12,822.15	[1] 8,000.00
	20	Franklin	23.520	Gravel	Dec. 14	222,133.83	107,000.00
	27	Columbia		...do	Dec. 21	[1] 35,957.43	[1] 17,000.00
	28	St. Francis		...do	Dec. 11		[1] 20,000.00
	43	Lincoln and Desha.		Gravel macadam.	Nov. 30		[1] 3,500.00
	50	Phillips	7.940	Bituminous concrete on concrete base.	Dec. 30	224,565.00	36,800.00
	66	Little River.	34.140	Gravel	Dec. 11	121,222.48	65,000.00
	67	Dallas	19.030	...do	Dec. 20	103,007.85	30,000.00
	75	...do		Gravel macadam.	Dec. 11		[1] 10,000.00
	87	Pope	8.140	Bituminous macadam.	...do	111,180.01	50,000.00
	109	Baxter	6.820	Water-bound macadam.	Dec. 31	54,506.85	20,000.00
	114	Lonoke	2,840	Gravel	Dec. 11	22,249.37	7,800.00
Colo.	112	Park	.758	...do	Dec. 24	28,197.84	14,098.92
	120	Jefferson	1.273	Concrete	...do	59,564.42	25,460.00
Fla.	3	Jackson and Gadsden.		Bridge	Dec. 2	[1] $212,316.39	[1] $106,158.20
	31	Dade	[2] 5.475	Chert	Dec. 3	[1] 10,788.27	
	131	Jackson	7.074	Sand-clay	Dec. 4	95,511.83	47,755.61
Idaho	24A	Twin Falls	7.000	Concrete	Dec. 30	301,442.75	140,000.00
	27	Payette	16.720	Gravel	Dec. 20	193,931.38	96,965.69
	30A	Power	14.190	...do	Dec. 18	116,240.96	58,120.48
	40	Washington.	18.596	Sand-clay	...do	187,354.54	93,677.27
Ind.	16A	Lawrence	11.191	Concrete	Dec. 6	448,799.17	223,280.00
Kans.	33C	Bourbon	3.160	Bituminous macadam.	Dec. 10	32,619.46	9,480.00
	40A-F	Crawford	9.085	Earth and brick or concrete.	Dec. 3	304,923.17	58,285.00
	39A, 39B	...do	5.033	Earth	...do	96,056.99	25,165.00
	60A, 60B	Anderson	7.597	Gravel	Dec. 10	242,417.72	75,500.00
	66A, 66B, 66C, 66D	Crawford	11.269	Earth	Dec. 3	167,966.16	56,345.00

[1] Modified agreements. Amounts given are increases over those in the original agreement.
[2] Decrease in mileage.

PROJECT AGREEMENTS EXECUTED IN DECEMBER, 1920—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Ky.	11	Trigg	17.674	Gravel	Dec. 8	$336,660.84	$168,330.42
	21	Meade	13.566	Earth	Dec. 10	149,308.92	74,654.46
La.	12B	Ascension	.950	Gravel	Dec. 8	11,382.80	5,691.40
	19	St. Landry	11.310	Sand-clay	Dec. 1	187,344.77	93,572.38
	27A	Rapides	8.000	Gravel	Dec. 2	122,452.26	61,226.13
	60	Lafourche and Terrebonne.	4.760	do	Dec. 27	99,334.71	49,667.25
	68	Caddo	9.500	Bituminous concrete on stone base.	Dec. 8	371,102.72	185,551.36
	78	St. Martin	5.600	Gravel	Dec. 8	81,013.93	40,506.96
	23	Lafayette	1.130	do	Dec. 27	[1] 15,455.87	[1] 7,727.94
Me.	4	Penobscot		do	Dec. 22	[1] 6,760.21	[1] 3,380.10
	9	Cumberland.		Concrete	do	[3] 28,582.21	[1] 1,494.35
	15	Penobscot	7.440	Bituminous macadam.	do	277,630.46	138,815.23
	16	do	4.080	do	do	168,751.73	81,600.00
	28	Sagadahoc	1.310	do	do	44,338.41	22,169.20
Md.	7C		.551	Concrete	Dec. 9	[1] 20,481.64	[1] 11,020.00
	9A	Frederick	[2] .200	do	do	[1] 7,548.75	[1] 3,774.38
	12C	Carroll		do	Dec. 2	[1] 22,127.60	[1] 7,260.39
	26B	Baltimore	2.400	do	Dec. 9	81,123.79	40,561.89
Mass.	36C	Barnstable	8.043	Bituminous concrete.	Dec. 7	172,261.03	86,130.51
Mich.	33A B	Alcona	12.866	Gravel and concrete.	Dec. 8	199,144.60	98,143.69
	41	Oakland	10.047	Concrete	Dec. 10	556,923.29	200,940.00
Minn.	58	Nobles		do	Dec. 4		[1] 6,000.00
	90	Rock	7.020	Gravel	Dec. 10	68,269.43	25,000.00
	94	Polk		do	do		[1] 16,000.00
	136	Beltrami	2.970	do	Dec. 20	18,520.86	9,000.00
	170	Mille Lacs	17.639	do	Dec. 8	254,522.60	127,261.30
	176	Itasca	7.430	do	Dec. 10	45,729.24	10,000.00
	185	Jackson		do	do		[1] 7,635.51
	186	Hennepin	3.800	Earth	Dec. 4	51,215.17	15,293.20
	191	do	1.420	do	Dec. 10	10,072.30	4,900.00
	197	Dakota	.910	Bitulithic	Dec. 24	47,251.35	18,200.00
Miss.	31	Alcorn	3.194	Gravel	Dec. 7	43,832.74	21,916.37
	40	Monroe		do	Dec. 3	[1] 3,182.58	[1] 1,591.29
Mont.	95B	Hill	10.320	do	Dec. 16	89,413.54	44,706.77
Nebr.	11	Gosper		Earth	Dec. 22	[1] 4,500.36	[1] 2,250.23
	25	Gage and Jefferson.		do	do	[1] 19,344.85	[1] 9,672.43
	35A	Douglas		Earth	Dec. 21	[1] 2,906.47	[1] 1,453.24
	60A	Howard		Earth and sand-clay.	do	[1] 751.68	[1] 375.84
	64	Pierce		Earth	do	[1] 3,115.93	[1] 1,557.96
	146A	Kieth	13.636	Sand-clay	do	75,656.26	37,828.13
N. H.	42	Shafford	[2] .400	Gravel	Dec. 8	[3] 19.75	[3] 9.88
	93	Belknap	.650	Stone macadam.	do	12,010.46	6,005.23
	99	Coos	[2] .170	Gravel	do	[1] 327.10	[1] 163.55
	107	Merrimack	.800	do	do	14,829.18	7,414.59
	118	Grafton	.310	do	do	10,031.56	5,015.78
	121	Sullivan	1.060	do	do	20,000.83	10,000.41
	126	Rockingham.	.580	Gravel, surface treated.	do	9,926.97	4,963.48
	128	Merrimack	.620	Gravel	do	17,889.19	8,944.59
	130	Grafton	.480	do	do	8,245.31	4,122.65
N. Mex.	4	Valencia		Earth	Dec. 10	[4] 33,175.19	[4] 16,587.59
	12	Chaves		Gravel	do	[4] 1,088.39	[4] 544.20
	14	Santa Fe		do	do	[1] 1,551.03	[1] 775.51
	36	Sandaval	5.871	do	do	43,848.31	21,924.15
	49	Otero	11.572	Caliche	do	47,246.77	23,623.38
	45	Luna	5.599	Gravel	Dec. 14	43,780.69	21,890.34
	34B	Rio Arriba	11.968	do	Dec. 23	105,590.70	52,795.35
	42	Socorro	17.157	do	Dec. 14	55,778.03	27,889.01
S. C.	7	Horry	[1] .277	Sand-clay	Dec. 18	[1] 27,069.16	[1] 13,534.58
	40	Allendale	10.165	do	Dec. 1	94,115.64	47,057.82
	64	Lexington	4.948	Topsoil	Dec. 18	43,833.80	15,000.00
	61	Darlington	19.676	Sand-clay	do	144,052.89	67,541.70
	65	Newberry	4.231	Topsoil	Dec. 10	39,011.76	19,505.88
	78A	York	5.031	do	Dec. 18	24,909.15	12,000.00
	83	Union	1.435	do	do	14,358.22	5,395.89
	98	Greenville	2.121	Concrete	do	124,590.22	42,420.00
Tenn.	20	Fentress	14.320	Water-bound macadam.	do	344,163.06	172,081.53
	43	Shelby		Bituminous macadam.	do	[1] 89,137.91	[1] 44,568.95
Tex.	39	Dallas		Concrete	Dec. 23		[1] $17,124.38
	89	Wood	9.830	Gravel	do	$64,394.24	22,000.00
	46B	Gillespie	9.990	do	do	92,137.91	32,320.00
	53C	Jefferson	1.920	Sheet asphalt.	do	69,213.27	34,606.63
	92	Hood		Earth	do		[1] 20,066.03
	109	Schleicher		Gravel	Dec. 20	[1] 47,032.68	[1] 30,366.52
	128B	Montague	11.767	do	do	112,907.50	56,453.75
	145	Tom Green		Water-bound macadam, surface treated.	Dec. 23	[3] 46,258.26	[1] 10,208.16
	153	Rains		Gravel	do		[1] 11,500.00
	159	Shelby		do	do	[1] 38,287.98	[1] 30,385.42
	135	Schleicher		do	do	[1] 28,456.94	[1] 14,228.47
	162	Potter	14.730	Gravel, surface treated.	do	542,182.08	200,000.00
	169	Dickens	7.560	Gravel	Dec. 20	38,236.94	19,118.47
	173	Travis	6.040	Gravel, surface treated.	Dec. 23	100,650.04	46,299.02
	184	Falls	.770	Gravel	Dec. 20	12,056.02	6,028.01
	187	Bastrop	8.730	do	do	78,939.27	34,496.34
	191A	Milam	5.720	do	Dec. 23	57,879.07	28,939.53
	193	Bexar	6.200	Gravel, surface treated.	do	124,609.07	58,168.43
	195	Falls	6.780	Gravel, bituminous.	Dec. 20	160,599.91	80,000.00
Utah.	5	Boxelder		Bituminous concrete.	Nov. 30	[1] 54,822.48	[1] 27,411.24
	14	do	.412	do	Dec. 31	19,283.47	8,080.00
Va.	32	Fairfax	1.726	Bituminous macadam.	do	[1] 94,597.52	[1] 47,298.76
	43	Albemarle	7.300	Water-bound macadam.	Sept. 25	214,475.86	107,237.93
	61A	Augusta	2.225	Bituminous macadam.	Dec. 28	68,114.80	34,057.40
Wash.	26	Grays Harbor.		Concrete	Nov. 4	[1] 19,800.00	[1] 9,900.00
	33	Clarke		do	Dec. 4	[1] 23,724.63	[1] 11,797.50
	32	Cowlitz		Gravel	do	[5] 20,501.63	[5] 10,250.79
	35	Whitman		do	do	[1] 36,257.84	[1] 17,050.40
	36	Clarke		Concrete	Dec. 9	[1] 9,000.47	[1] 4,500.24
	46	Garfield		Crushed rock.	do	[1] 21,816.52	[1] 10,798.64
	47	Columbia		Gravel	Dec. 4	[1] 7,748.40	[1] 3,848.68
	61	Lewis		do	do	[1] 6,831.77	[1] 2,426.72
	65	Okanogan	1.990	do	do	35,670.91	17,800.00
	71	Columbia and Garfield.	8.640	Crushed rock.	do	40,374.40	20,000.00
	72	Grays Harbor.	1.710	Concrete	do	71,681.83	34,200.00
W. Va.	4	Marion		Concrete		[1] 39,542.33	[1] 18,560.00
	58A	Pleasants	2.800	Earth	Dec. 8	50,000.00	25,000.00
	85	Roane	3.000	Concrete	Dec. 17	64,768.00	27,200.00
	82A	Gilmer	5.000	Earth	Dec. 24	67,400.00	33,700.00
	77	Greenbrier	16.160	do	do	146,712.70	67,271.40
	95	Ohio	1.000	Reinforced concrete.	Dec. 21	42,357.60	13,290.00
	97	Marshall	3.000	Concrete	do	136,643.00	16,843.00
	98	Randolph	4.510	Bituminous macadam.	Dec. 17	80,613.20	39,040.00
	99	Webster	3.343	Earth	do	93,940.00	46,970.00
	[1] 100	Tucker	1.900	Concrete	Dec. 21	78,000.00	24,640.00
	101	Raleigh	4.410	Earth	Dec. 29	64,640.00	32,320.00
	102	Boone	3.120	do	Dec. 17	73,000.00	30,080.00
Wyo.	30	Natrona	4.078	Concrete	Dec. 15	368,597.17	103,787.15
	27A	Weston	3.333	Gravel	do	37,577.14	18,788.57
	43	Platte	[1] 1.182	Earth	do	[1] 15,583.70	[1] 7,791.85
	69	Johnson		Gravel	do	[1] 6,582.65	[1] 3,291.33
	77	Fremont		Bridge	do	20,577.15	10,288.57
	87	do		do	do	59,711.01	29,855.50
	82	Laramie and Goshen.	23.437	Gravel	do	193,677.63	96,838.81
	91	Platte	15.088	do	do	191,063.49	95,931.74
	94	Park		Bridge	do	16,199.70	8,099.85
	97	Sweetwater.	1.808	Earth	do	16,315.02	8,157.51
	98	Carbon	4.155	Gravel	do	35,484.61	17,742.30

[1] Modified agreements. Amounts given are increases over those in the original agreement.
[2] Decrease in milcage.
[3] Modified agreements. Amounts given are decreases from those in the original agreement.
[4] Modified agreements. Third revision, Increase.
[5] Modified agreements. Second revision. Increase.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free

REPORTS.

Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.
Report of the Chief of the Bureau of Public Roads for 1920.

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
*136. Highway Bonds.
220. Road Models.
230. Oil Mixed Portland Cement Concrete.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads
*537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
660. Highway Cost Keeping.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.
*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918. 15c.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS, BULLETINS.

F. B. 338. Macadam Roads.
*505. Benefits of Improved Roads. 5c.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir.*89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registration and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington D. C. 5c.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses and Revenues in the United States 1918. 15c.
*Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918. 15c.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration weedle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disprese Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 35 WASHINGTON, D. C. MARCH, 1921

ONE OF THE TRUCKS USED IN THE IMPACT TESTS

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number or $1.50 per year to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Motor Truck Impact Tests of the Bureau of Public Roads 3
Earl E. Smith

Report on California Highways Ready 36

Federal-Aid Allowances 37

Construction and Maintenance in Illinois 39

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

THE MOTOR TRUCK IMPACT TESTS OF THE BUREAU OF PUBLIC ROADS

By EARL B. SMITH, Senior Assistant Testing Engineer, Bureau of Public Roads.

HIGH POINTS OF THE REPORT.

Impact depends largely upon the kind and condition of the tire.

Thin or worn solid rubber tires, even though they be very wide, produce very high impact forces.

Pneumatic tires offer the greatest influence in reducing impact forces, and with their use the impact increases only very slightly with the speed of the truck.

Cushion tires, that is, tires having a degree of softness and deflection between solids and pneumatics, offer corresponding advantages in reducing impact.

Impact increases with the speed of the truck, but it can not be said to increase according to any constant ratio or power of the speed.

Although heavy unsprung weight may give higher impact than lighter unsprung weight, it can not be said that this is the major controlling factor.

The relative destructive effect produced by light-weight, high speed trucks and heavy, slow-moving trucks has not been determined by these tests. They do, however, indicate that equal impact may be obtained under some conditions.

Impact may be as high as 7 times the static load on one rear wheel when a solid-tired truck strikes a 1-inch obstruction at 16 miles per hour, an average value being about 4 times. For pneumatic tires the maximum impact value is probably not more than 1¾ times the load at one rear wheel, and an average value is not more than 1¼ times the load.

WHEN roads were built to carry the traffic of a few years ago they were built according to "experience" and empirical rules, and the actual weight or speed of the load was only generally considered. Much attention was paid to the question of whether the traffic was equipped with steel or rubber tires. Considerable stress was also placed on the relative tractive effort required on different types of surfaces. A definite analysis of the surface and supporting conditions of the road and a quantitative determination of destructive forces were not deemed necessary.

The transition from horse-drawn to automobile and truck traffic has changed the surface and strength requirements of a road. Heavy truck traffic has developed very rapidly. Within only a few months during the war the change was made from a tolerable traffic condition to that of heavy motor trucks operating at high speeds on solid rubber tires. This sudden development of a very severe form of traffic could not be met with an ample road-building program, nor could it be controlled or directed from the highways previously built and not suited for such traffic, with the result that many heretofore suitable roads were completely destroyed. With the realization that this heavy and severe traffic is here to stay and will probably increase in weight and density, means are being sought for constructing such roads as will carry this traffic. Engineers realize that the roads will have to be built according to very careful and thorough design, but are at once confronted with the fact that no design can be satisfactorily accomplished without knowing very definitely all the forces to which the road is subjected.

To obtain the value of the impact forces on roads has been the object of a series of investigations by the United States Bureau of Public Roads during the past two years. It is known that there are four important factors to be considered in road design, namely, impact, pressure or weight of the passing load, horizontal shear and tractive forces, subgrade and soil conditions. Each of these factors is being thoroughly investigated. More progress has been made in the study of impact than any of the other factors, and on this subject enough data has been collected to warrant a report at this time. This paper will deal only with the subject of impact.

ELEMENTARY STATEMENTS.

Some elementary statements of definition and fact will be necessary to understand the meaning and the limitations of the experimental data to be presented. The term "impact" in its ordinary use means the force with which a moving body strikes another body. The term is used here in this sense, and its specific application is to the force resulting when a truck wheel strikes

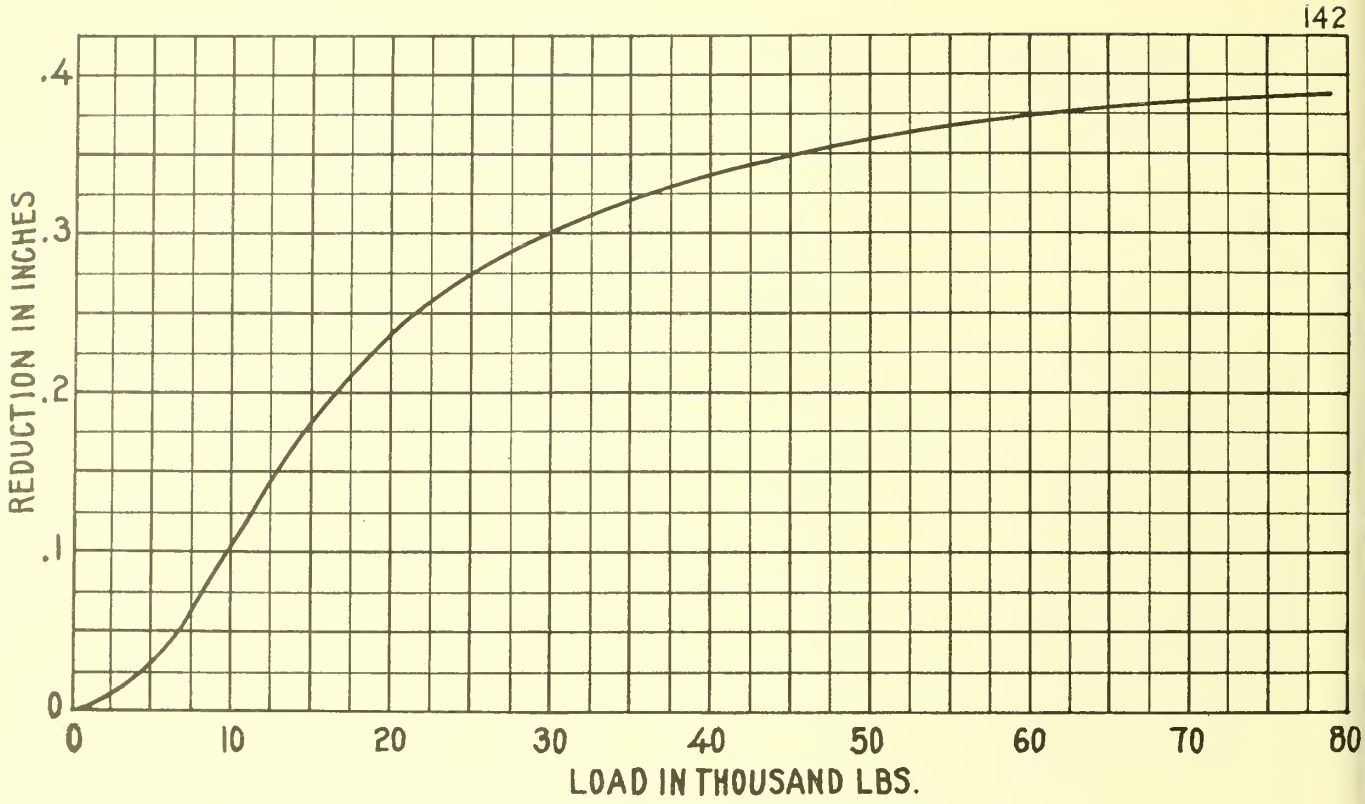


FIGURE 1.—STATIC LOAD DEFORMATION OF ½-INCH COPPER CYLINDERS.

the surface of a road. This action may occur when the wheel, traveling over the road surface, falls from one level to another, or when it strikes an obstruction and bounds upward and finally falls to the road surface. In the second case there is an impact reaction at the time of striking the obstruction and a second impact at the time of striking the road. The obstruction may be only an irregularity or wave in the road surface. The impact will vary in intensity with the speed of the truck. The impact considered here is only the force acting vertically or normal to the road surface. Other components will be less severe than the vertical, which is therefore the critical and controlling force.

IMPACT VS. STATIC FORCE.

The force of impact produces an effect somewhat different from that of a static force. Static forces produce simple deformations proportional to the force (within the elastic limit of the materials), but impact produces much more complex conditions of stress.

Static loads or forces are measured as only a single factor, i. e., as weight or pressure. An impact force is the result of mechanical energy or of mass times acceleration; it is a function of weight, distance, and time. If impact is measured in terms of energy, then there is no rational equivalent between the foot-pounds of impact and the pounds of a static force. A mass in motion does not produce impact unless it strikes or collides with another mass, then the intensity of the impact depends upon how quickly it is brought to rest, or upon the rate of change of the velocity of motion. This rate of change is known as acceleration; the change itself may be positive or negative, i. e., the velocity may be increased or decreased. To increase the velocity of a given mass requires that energy be expended upon it; if the moving mass be suddenly stopped by collision with another body it delivers energy to the mass against which it strikes. The exact value of the force in pounds with which one mass strikes another is very difficult of determination. When the moving body strikes, it does work in overcoming resistances, and does not come to rest until all of its energy has been expended. The resistances met with are due to the inertia of the body struck, and to the deformation

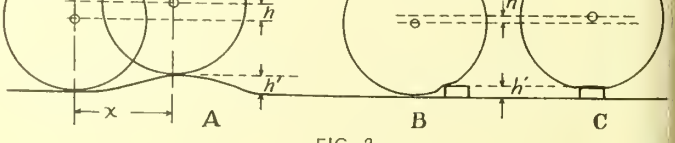


FIG. 2.

and heating of both bodies. The exact values of these resistances, as well as the distance through which they act, are difficult to determine. The other important factor in governing the value of the force of impact is time; if the time required to overcome the resistances, or the time consumed in coming to rest, is zero, then the force is indefinite. The longer the time required to come to rest the smaller will be the impact force.

TRUCK EQUIPPED WITH PNEUMATIC TIRES PASSING OVER OBSTRUCTION.

Although the exact value of impact forces is difficult of determination, there seems to be an approximate connection between the deformation effects of static and impact forces which may be utilized in making a comparison. In other words, since each force may be made to produce a deformation, we may express an impact force as equivalent to a static force which causes the same deformation. This is not, of course, entirely satisfactory; it is a permissible approximate comparison, and is only practical in its application when the load or force producing the impact is large and moving at a moderate velocity. It may readily be seen that a large weight moving at a small velocity will produce a different destructive effect than a small one moving at a very high velocity, although the kinetic energy measured in foot-pounds is the same in both cases. Two methods are available for determining the value of impact: (*a*) By receiving the impact on some material, the deformation of which will be proportional to the force applied, and comparing this deformation with that produced by a steadily applied or static force; (*b*) by determining autographically the velocity and maximum deceleration of the mass when it strikes the resisting body. A description of these two methods may be of interest.

METHODS OF DETERMINING IMPACT FORCES.

In employing the deformation method a copper cylinder is used as the body upon which the impact is received. These cylinders are cut from round copper rods one-half inch in diameter, and machined to 0.500 inch in length. They are heat treated to secure uniformity of stress resistance, that is, to make them all of equal softness. In use, one copper cylinder is placed in the bottom of a heavy cylinder under a loose but neat fitting plunger, and the impact is received on the head of the plunger. The deformation of the copper thus produced is then measured with a micrometer and compared with the deformations produced by static forces. This comparison has been simplified by determining and plotting a "deformation vs. static load" curve (see fig. 1); from which, knowing the deformation, it is easy to determine the equivalent static load. This method of determining impact values gives results that are reliable and can be closely checked. The disadvantage of it is that the copper cylinder itself introduces another factor in the result; it acts as a cushion and thus serves to reduce the value of the impact. It should also be remembered that the copper cylinder under impact does not measure force alone, but measures work, i. e., the work which is done upon it when the moving mass is brought to rest and its kinetic energy is overcome; moreover, the impact measured by the cylinder is an average value, not a maximum. At the instant of touching the copper cylinder the force of impact is zero, and at the point of coming to rest it is probably a maximum; then the average force or resistance of the copper multiplied by the deformation or distance through which it acts must be equal to the energy applied (heating and elastic effect neglected). It will, therefore, be seen that the deformation, or copper cylinder method, of determining impact values will show approximately the average force of impact. The maximum value of the impact force may be nearly twice as great, the exact value depending upon whether the load deformation curve of the copper is a straight line or is parabolic in shape.

THE AUTOGRAPHIC METHOD.

The autographic method is accomplished by the use of a curve drawn autographically on a tape of paper with a pencil operated by the vertical movement of the mass. The paper tape is moved at right angles to the pencil movement at a known uniform speed. This produces a "space-time" curve, the ordinates of which are space or distance passed over by the mass; the

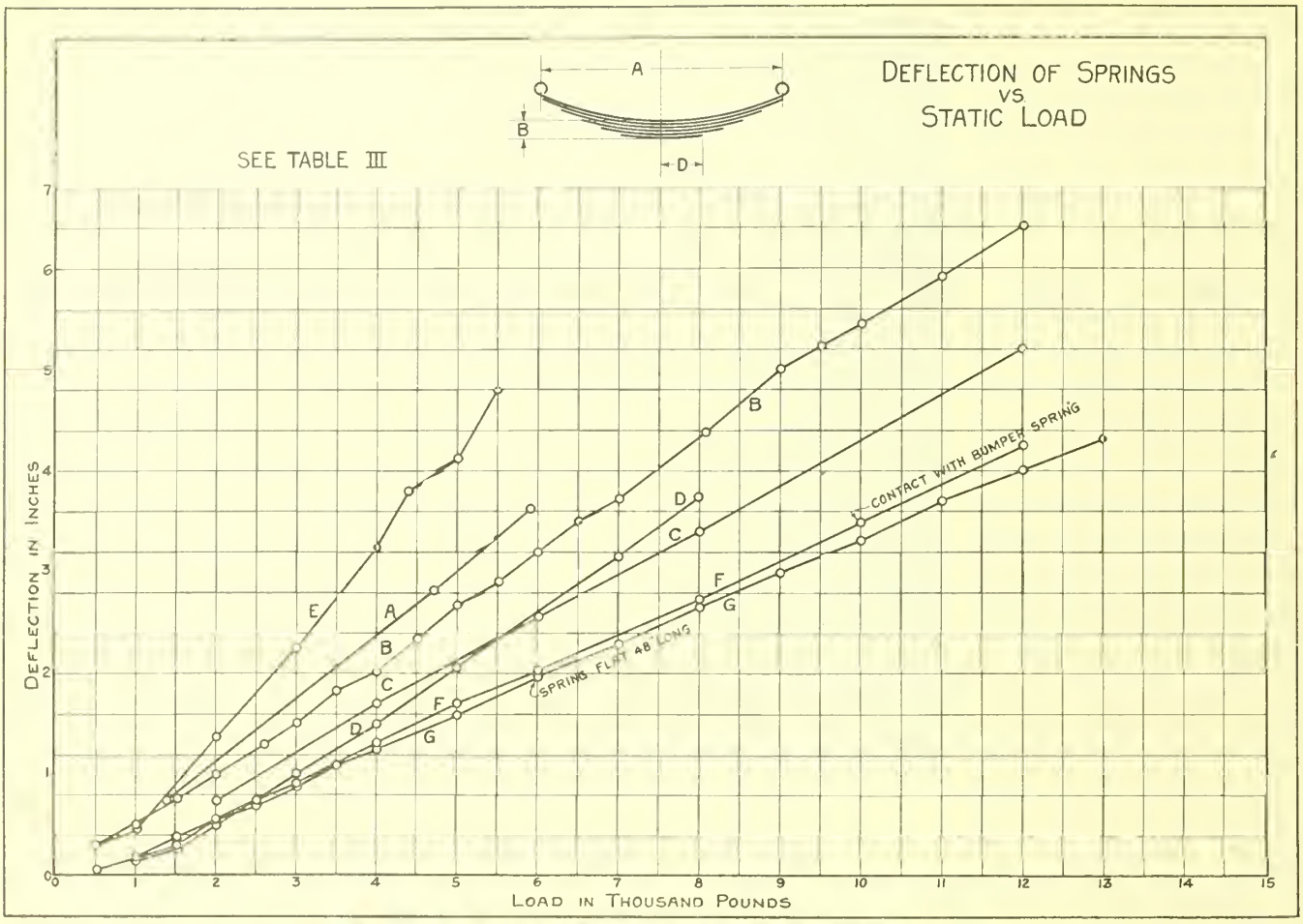


FIG. 3.—STATIC LOAD VS. DEFLECTION OF SPRINGS.

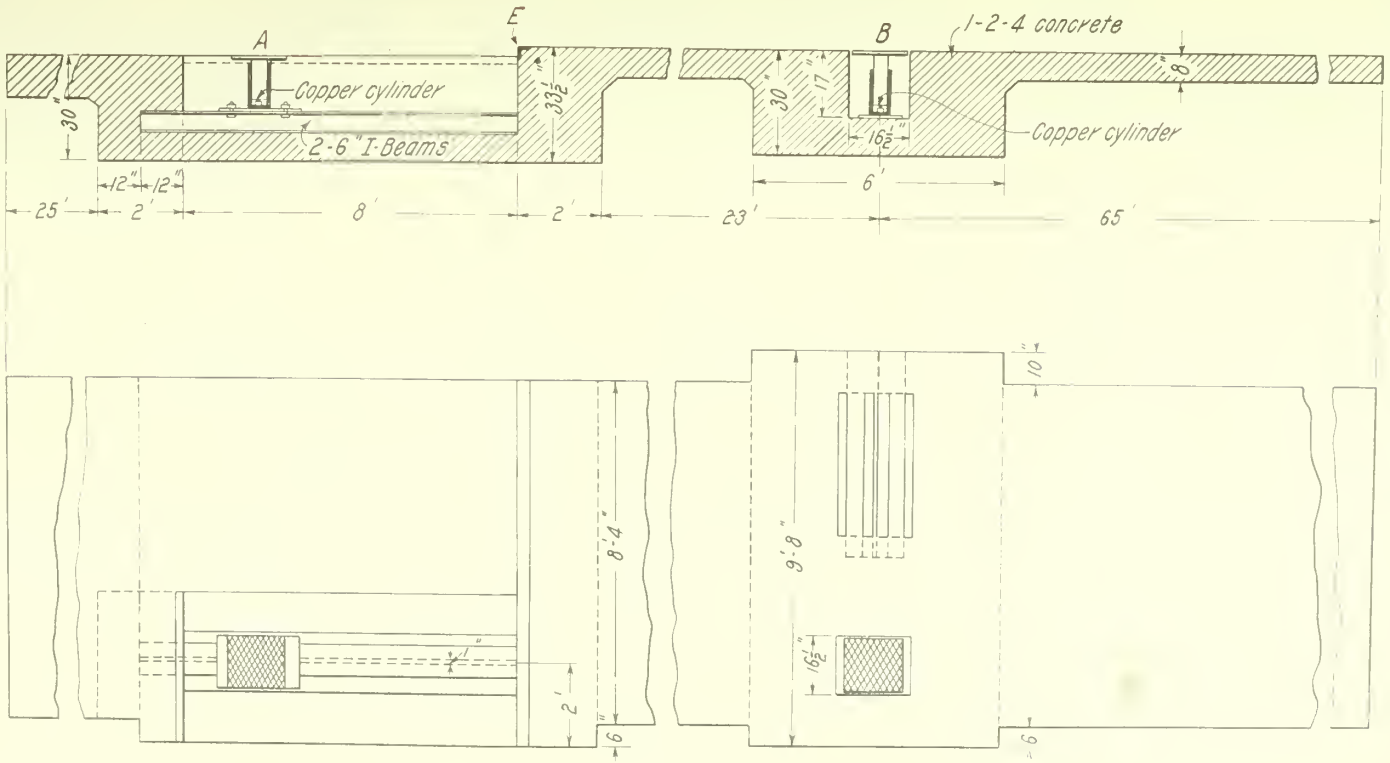
abscissæ being the corresponding units of time. The second derivative of this curve will give the acceleration at any desired point. The maximum acceleration will be at or near the point of impact; then knowing the mass and its acceleration we have the result from the fundamental relation, "mass multiplied by acceleration is equal to force." This is the force of impact. The method just described has been used only to a very limited extent and none of the results given in this paper was obtained in this way. But in subsequent tests, when actual road conditions will be investigated, this method will have to be used, since the copper cylinder method is not practical under such conditions.

THE ACTION OF A MOVING TRUCK.

A truck wheel moving over a perfectly smooth and rigid plane surface will produce on that surface a pressure equal to the total weight of the wheel and its load. But if the surface is uneven, wavy, or rough a pressure may be produced which will be greater than the static load, its magnitude depending upon several factors. The resulting pressure or force upon the surface will be considered to be an impact when it is greater than the static load of the wheel.

A motor truck consists essentially of four wheels carrying a body on intervening springs, and an impact may occur at any one or all of the wheels. The characteristics of a truck and the factors which enter into the determination of impact values are the sprung weight, or all weights and loads above the springs; the unsprung weight, which includes wheels, tires, axles, springs, and all other effective weights under the spring; the kind and condition of the tire; the spring characteristics, which include its deformation or deflection under different loads and its period of vibration; the horizontal speed of the truck; the size and shape of the obstruction, or irregularity in the surface over which the wheel passes; and the character of the road surface.

The greater proportion of the weight of a truck is carried on the rear wheels, and while the front wheels do cause some impact the rear wheels, in general, will cause greater impact. In all discussions of impact forces from motor trucks it is the effect at one rear wheel only which will be considered, since here the force of impact is greatest and it is at this point that the controlling factors have the greatest influence. Of course, if both rear wheels are subjected to the same road influences at the same time, the impact of each wheel will be the same and the result will be the application of equal impact forces to the road surface at the two wheel points.



SPECIAL CONCRETE ROAD CONSTRUCTION FOR IMPACT TESTS OF TRUCKS ON ROADS

SPRUNG AND UNSPRUNG WEIGHTS.

The sprung weight of a truck produces deflection in the spring and tire and consequently a pressure on the road surface. This weight takes on a comparatively slow up-and-down movement when the truck wheel strikes an obstruction or irregularity. This movement

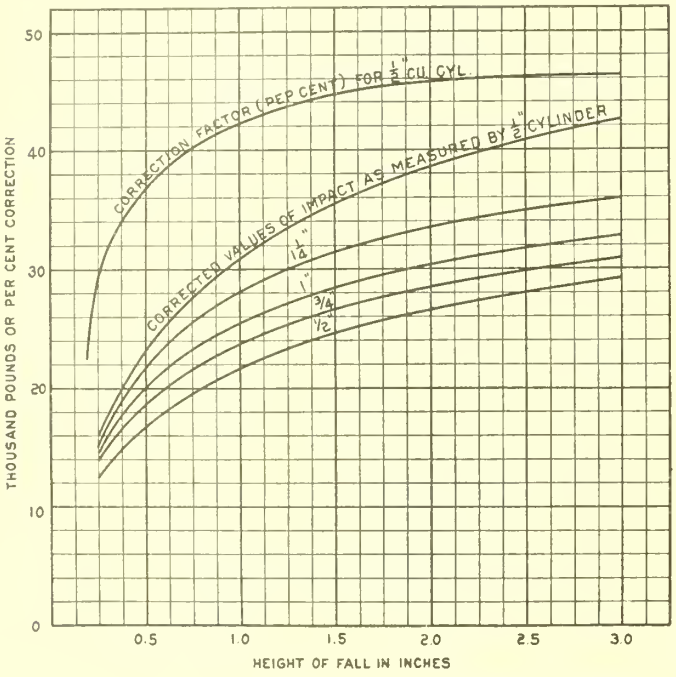


FIG. 5.—CUSHIONING EFFECT OF COPPER CYLINDER.

which is slight at the instant of contact, increases to a maximum, at some time after the wheel impact and produces intensified road pressures which may be greatly more than the static load.

The unsprung parts of the truck act in an entirely different manner. When the wheel strikes an obstruction in the road it acquires an upward velocity depending upon the height of the obstruction and the speed of the truck. The reaction or impact on the road surface is a force depending for its value upon the vertical acceleration of the wheel, the mass of the unsprung parts and the spring pressure. The wheel may continue to move upward even after passing the obstruction until the movement is overcome by spring pressure and inertia, it is then shot downward by the combined action of gravity and spring pressure, and thus produces another impact on the road surface. The vertical reaction of this movement of the unsprung parts serves of course slightly to retard the fall of the body or sprung parts of the truck; but when the body does fall and is cushioned on the springs, it produces an additional pressure on the road surface, but strictly speaking not an impact. It will readily be seen that the magnitude of the impact as the wheel passes over obstructions and irregularities, and also the oscillations of the sprung weight are dependent upon the speed of the truck.

It is the unsprung weight and the value of the spring pressure which produces the actual impact, and since impact is a force resulting from a moving mass being brought to rest with a negative acceleration, it is greatest when "mass times acceleration" is a maximum. Acceleration being the change of velocity within a certain time, it is seen that if the final velocity is zero the greater the actual velocity just before impact the greater will be the value of the negative acceleration, or deceleration.

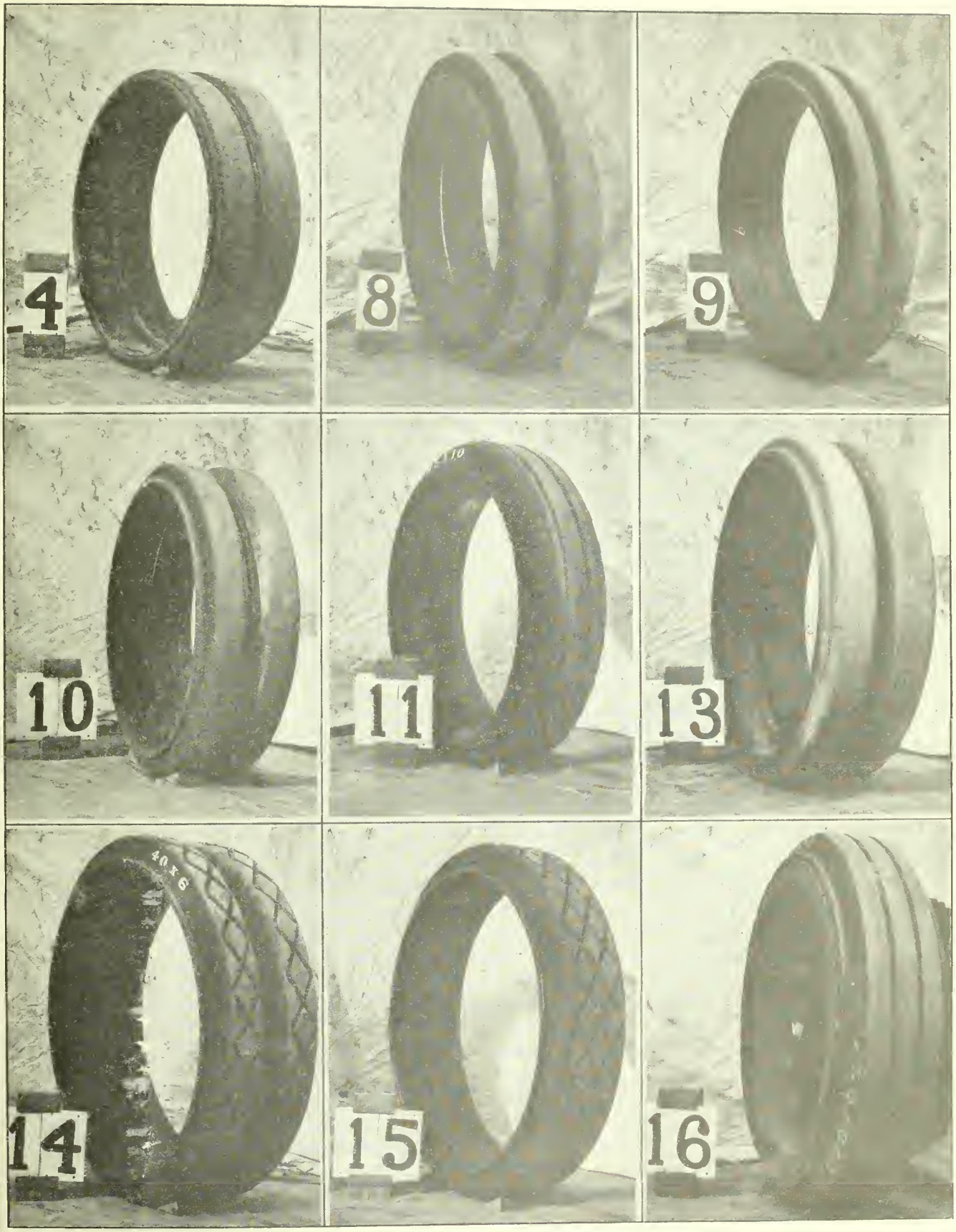
In the case of a wheel striking an obstruction or a wave the vertical velocity depends upon the horizontal speed, the height and form of the obstruction, and the indentation or the deflection of the tire when striking. Taking the simpler case (fig. 2A), the wheel mounts the wave gradually with a more or less localized tire deflection and must attain the height h, while the wheel is passing horizontally over the distance x, at the speed S. In this case the vertical velocity

$$v=\frac{1.46Sh}{x} \quad \ldots\ldots\ldots\ldots (1)$$

where S is measured in miles per hour, and h and x are measured in feet; the resulting velocity v is in feet per second.

If the wheel strikes a sharp obstruction, as in figure 2B, the tire action has considerable influence upon the result. After striking, the wheel rises and approaches the position at C. Somewhere between these two positions the vertical velocity will be a maximum. The mean velocity is given by the same relation as in equation (1), except that h is the height of rise of the wheel and not the height of the obstruction. How greatly these two values will differ depends upon the character of the obstruction and the tire. One extreme is where the tire and obstruction are practically incompressible, as a steel tire and stone block, then $h=h'$. The other extreme would be with a soft pneumatic tire which would indent or deflect an amount equal to h', then $h=0$, and $v=0$. In this consideration it should be noted that in obtaining the vertical velocity the weight of the sprung or unsprung parts is not a factor, while the speed of the truck is a main factor. It is also assumed that the radius of the wheel is at least five times the height of the obstruction, so that the horizontal retardation of the truck is of no appreciable consequence.

Let us consider the action of a truck wheel in falling from one elevation to another, or in falling after having been thrown upward as a result of striking a wave or obstruction with sufficient horizontal velocity to make the wheel jump clear from the road surface. In such cases, the wheel is acted upon by gravity and the downward spring pressure. If the wheel and truck body as a whole have been thrown upward to some considerable height, say 1 to 2 feet, then the spring pressure becomes zero. While the truck is in flight the wheel vibrates up and down freely under the influence of the spring, and practically comes to rest with respect to the truck body before it strikes the road surface



TYPES OF TIRES USED IN THE EXPERIMENTS.

33108—21——2

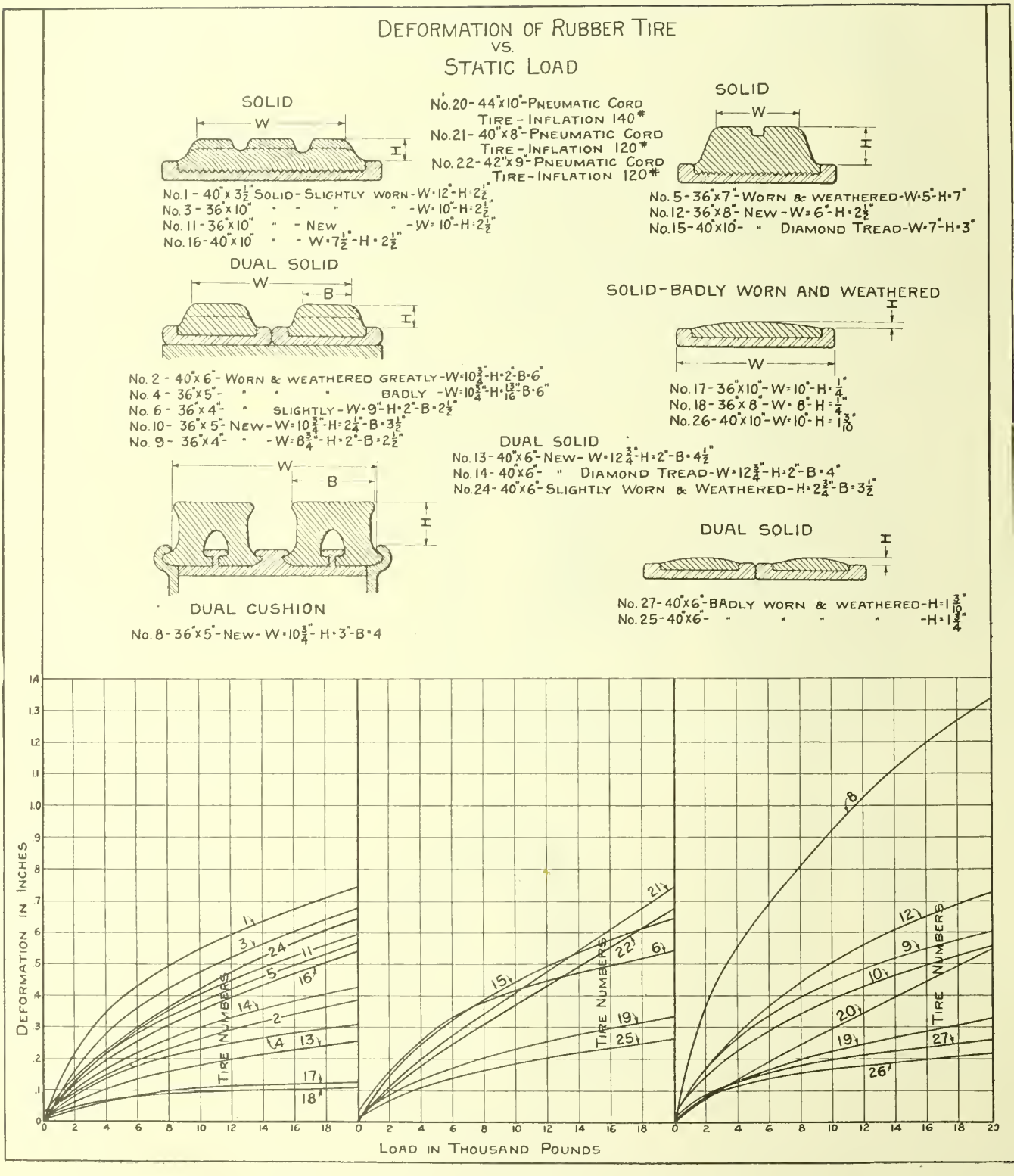
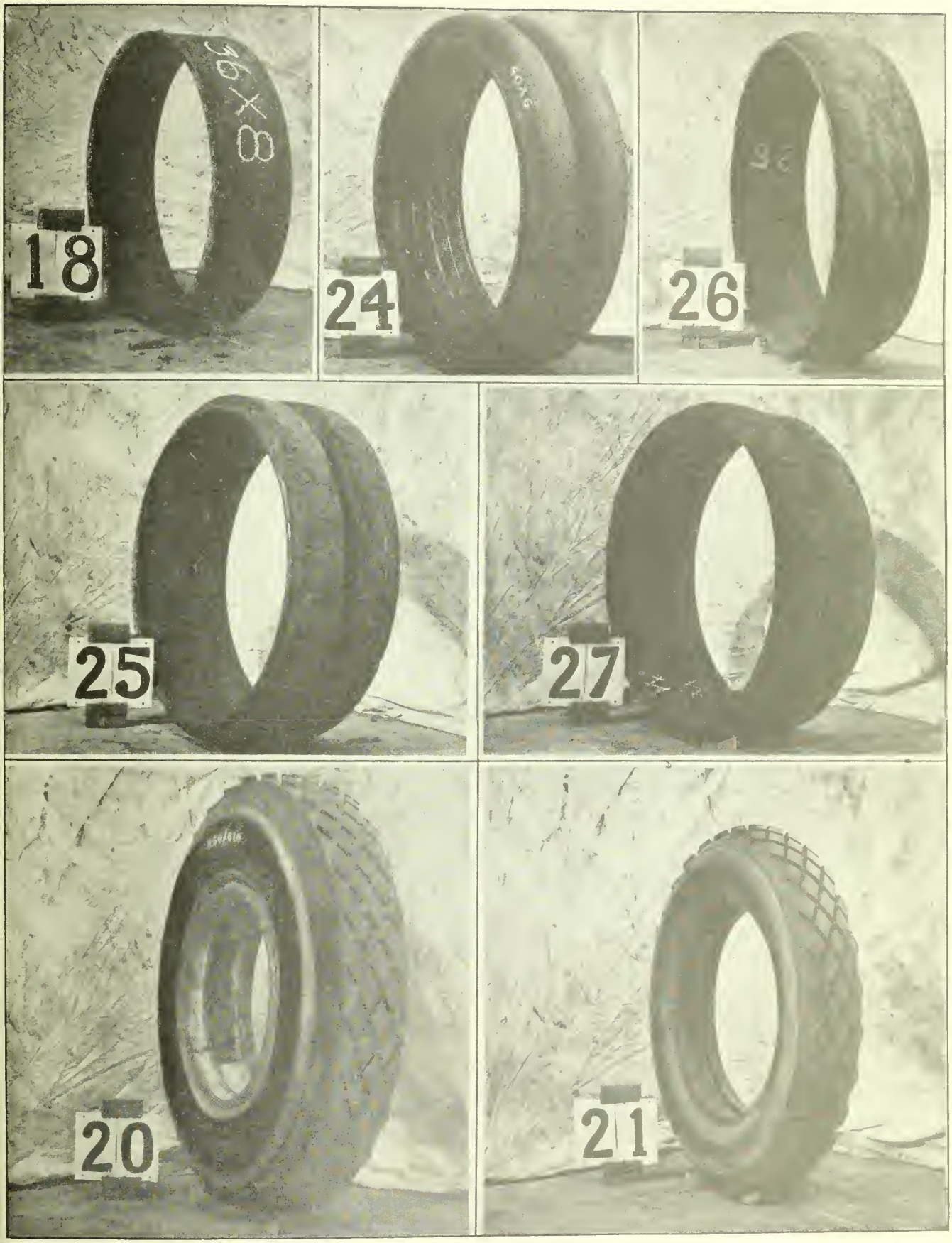

DEFORMATION OF RUBBER TIRE
VS.
STATIC LOAD
SOLID
W
H
No. 1 - 40"x3½" SOLID - SLIGHTLY WORN - W=12" - H=2½"
No. 3 - 36"x10" " - " " - W=10" - H=2½"
No. 11 - 36"x10" " - NEW - W=10" - H=2½"
No. 16 - 40"x10" " - W=7½" - H=2½"
No. 20 - 44"x10" - PNEUMATIC CORD TIRE - INFLATION 140#
No. 21 - 40"x8" - PNEUMATIC CORD TIRE - INFLATION 120#
No. 22 - 42"x9" - PNEUMATIC CORD TIRE - INFLATION 120#
SOLID
W
H
No. 5 - 36"x7" - WORN & WEATHERED - W=5" - H=7"
No. 12 - 36"x8" - NEW - W=6" - H=2½"
No. 15 - 40"x10" - " DIAMOND TREAD - W=7" - H=3"
DUAL SOLID
W
B
H
No. 2 - 40"x6" - WORN & WEATHERED GREATLY - W=10¾" - H=2" - B=6"
No. 4 - 36"x5" - " " " BADLY - W=10¾" - H=1 15/16" - B=6"
No. 6 - 36"x4" - " SLIGHTLY - W=9" - H=2" - B=2½"
No. 10 - 36"x5" - NEW - W=10¾" - H=2¼" - B=3½"
No. 9 - 36"x4" - " - W=8¾" - H=2" - B=2½"
SOLID - BADLY WORN AND WEATHERED
H
W
No. 17 - 36"x10" - W=10" - H=¼"
No. 18 - 36"x8" - W=8" - H=¼"
No. 26 - 40"x10" - W=10" - H=1 3/10"
DUAL SOLID
No. 13 - 40"x6" - NEW - W=12¾" - H=2" - B=4½"
No. 14 - 40"x6" - " DIAMOND TREAD - W=12¾" - H=2" - B=4"
No. 24 - 40"x6" - SLIGHTLY WORN & WEATHERED - H=2¾" - B=3½"
W
B
H
DUAL CUSHION
No. 8 - 36"x5" - NEW - W=10¾" - H=3" - B=4
DUAL SOLID
H
No. 27 - 40"x6" - BADLY WORN & WEATHERED - H=1 13/16"
No. 25 - 40"x6" - " " " " - H=1¾"
DEFORMATION IN INCHES
LOAD IN THOUSAND POUNDS
TIRE NUMBERS
1
3
24
11
5
16
14
2
4
13
17
18
TIRE NUMBERS
21
22
6
15
19
25
TIRE NUMBERS
8
12
9
10
20
19
27
26

FIG. 6.—STATIC LOAD VS. DEFORMATION OF RUBBER TIRE.



TYPES OF TIRES USED IN THE EXPERIMENT.

again. The wheel and the body are then acting as a unit and are falling freely under the influence of gravity only. They have a downward velocity due only to the height of fall, the final velocity v being given by the equation

$$v = \sqrt{2gh} \quad \ldots \ldots \ldots \ldots \quad (2)$$

The actual performance of the truck in motion over a road surface is not such as to cause it to be in flight at such a height nor for a sufficient length of time to permit the vibration of a wheel under the influence of the spring to die out, so that there is no relative movement

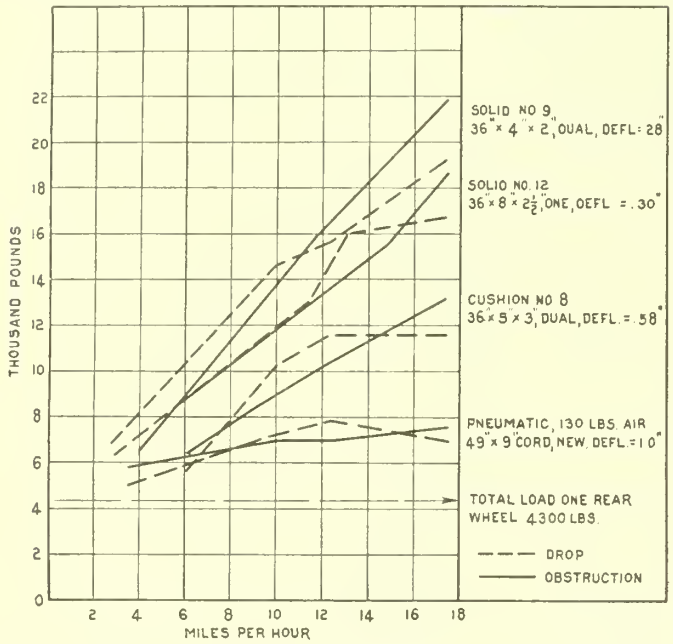

THOUSAND POUNDS
MILES PER HOUR
SOLID NO 9
36" x 4" x 2" DUAL, DEFL: 28"
SOLID NO 12
36" x 8" x 2½" ONE, DEFL = .30"
CUSHION NO 8
36" x 5" x 3" DUAL, DEFL. = .58"
PNEUMATIC, 130 LBS. AIR
4.9" x 9" CORD, NEW, DEFL = 1.0"
TOTAL LOAD ONE REAR WHEEL 4,300 LBS.
DROP
OBSTRUCTION

FIG. 7.—COMPARISON OF TIRES (TRUCK, 2-ton A.; LOAD, 2 TONS; (UNSPRUNG WEIGHT), mg., 1,000 LBS.).

between the wheel and body. If, therefore, a truck wheel be suddenly released from its road support and drops to a lower surface it does so under the combined influence of gravity and spring pressure. The spring pressure is a maximum at the beginning of the drop and a minimum at the end. In the case of a direct drop from one level surface to another, the initial spring pressure is equal to the load carried, and the final spring pressure depends upon the stiffness of the spring and the amount it has opened. Spring deflections usually vary directly with the load, and range in value up to 6 or 8 inches. The stiffness varies for different truck springs from 1,000 pounds to 3,000 pounds per inch of deflection. See figure 3. Irregularities and falling distances in road surfaces are usually less than 2 inches, most of them being under 1 inch. It will therefore be seen that the usual drop or action of a wheel is always within the range of influence of the spring. The fact should also be realized that the motion of the body or sprung weight of the truck is not appreciable until some time after the disturbing event has occurred.

In a simple way we may consider the truck wheel as a single mass acted upon by gravity and by a spring pressure, then the velocity at the end of the fall is

$$v = \sqrt{2gh} + at \quad \ldots \ldots \ldots \ldots \quad (3)$$

(g is 32.2, the acceleration of gravity; h is the height of fall in feet; t is the time of fall in seconds; and, a is the acceleration due to spring pressure).

That is, as shown by equation (3), the velocity attained under the combined action of gravity and spring pressure is equal to the velocity attained under free fall plus a velocity which is a function of the acceleration due to spring pressure. This acceleration is not constant, since the force producing it is not constant; its value depends upon a complex integral equation.

Solution of equation (3) shows that the vertical velocity of the truck wheel falling or acting within the influence of the spring pressure is very much greater than when falling free from a considerable height. While we are not concerned directly with the value of the velocity, it is a factor which enters into the determination of the final deceleration.

The final force of the blow is dependent upon how quickly the mass is brought to rest. Since acceleration is dependent upon the rate of change of velocity from the instant of touching the road surface to the instant when the mass is finally at rest, it is readily seen that the shorter the time and distance over which this change takes place the greater will be the force. This, also, applies when the mass starts from rest, or zero, and is changed to some maximum value as the wheel rises vertically over a wave or obstruction.

The rate of change, that is, the acceleration or deceleration, is determined by the time necessary to change the velocity from one value to another. In the cases with which we are now concerned, either the final or initial velocity is always zero. Therefore, if the time required to change the vertical velocity of a wheel to zero can be determined, we may obtain the acceleration by dividing the initial velocity by this time. This time interval, however, is very difficult to determine in any way except by means of some autographic recording device.

EFFECT OF TIRES.

The time element in the rate of change of velocity varies with the distance over which the change takes place. If a vertically moving wheel with a steel tire strikes a hard rigid road surface it is brought to rest in a very small vertical distance, and consequently in a very small time; therefore, the deceleration value will be large, producing a large impact force. If the wheel carries a solid rubber tire it will be brought to rest in a somewhat greater distance and time, and the result will be a smaller deceleration value and less impact. The greater the tire deflection, or cushioning effect, the

less will be the impact value. This is as should be expected, and the fact is very clearly shown in the experimental results.

OTHER DESTRUCTIVE EFFECTS OF TRUCKS.

Because of the large amount of power and tractive effort a large shearing force is applied by the two rear wheels to the road surface. In the case of hard surfaced roads this has no particular destructive effect. But in the case of loose surfaced roads, such as gravel, sand clay, and waterbound macadam, tractive forces may be very destructive. However, this may not be any greater in the case of trucks than it is for pleasure cars running at high speeds.

Trucks, which under load have a total weight of 20,000 pounds, may have in most types of construction a single rear wheel load of 7,000 to 8,000 pounds. This as a simple static load is often sufficient to break through some roads.

While an impact is the most severe and the most frequent of the forces produced by a truck passing over an imperfect road surface, there is another effect of increased road pressure which should be understood. When a truck passes over a road surface, even if at such a speed as to produce little or no actual wheel impact, the irregularities and waves in the road cause the body to oscillate up and down. This oscillation is not a simple vibration, but is rather complex with respect to its amplitude and period. On each downward oscillation of the body, the springs are compressed to a greater amount than that due to the static or dead load. This greater spring deflection produces a correspondingly greater pressure on the road surface. As an example, considering the effect at one rear wheel: A truck is carrying on the rear spring, 8,000 pounds; the unsprung weight is 1,500 pounds; the spring deflection under its load is 4 inches; the oscillation causes the load in falling to deflect the spring an additional 4 inches, which from observation is entirely reasonable; then we have—

	Pounds.
Actual load	8,000
Addition load from 4 inches additional spring deflection	8,000
Unsprung weight	1,500
Total oscillation effect, at one rear wheel	17,500

This could be further added to by wheel impact. Combinations of impact and oscillations very often occur at the same instant; then the oscillation effect would be added to the impact effect. Suppose at this same instant an impact force of 10,000 pounds had occurred, then the total road pressure would be 17,500 + 10,000 = 27,500 pounds at one rear wheel.

The additional road pressure due to the oscillation of the body is only very slightly affected by the kind and condition of the tire. This is because we are dealing with the sprung weight and the spring is cushioning this weight far more than is the tire; it is not in the nature of an impact but only similar to a suddenly applied load.

EFFECT OF THE UNSPRUNG WEIGHT.

In order to consider the effect of the unsprung weight on the value of the impact produced by a truck on the road surface, it must be realized that a truck wheel can not be isolated from the influence of the truck spring, either in its upward or downward movement. The effect of the unsprung weight can not be said to bear a definite fixed ratio to the effect of the load carried by the truck.

In the *downward* movement of the unsprung weight, in flight free from the road surface, its velocity at any

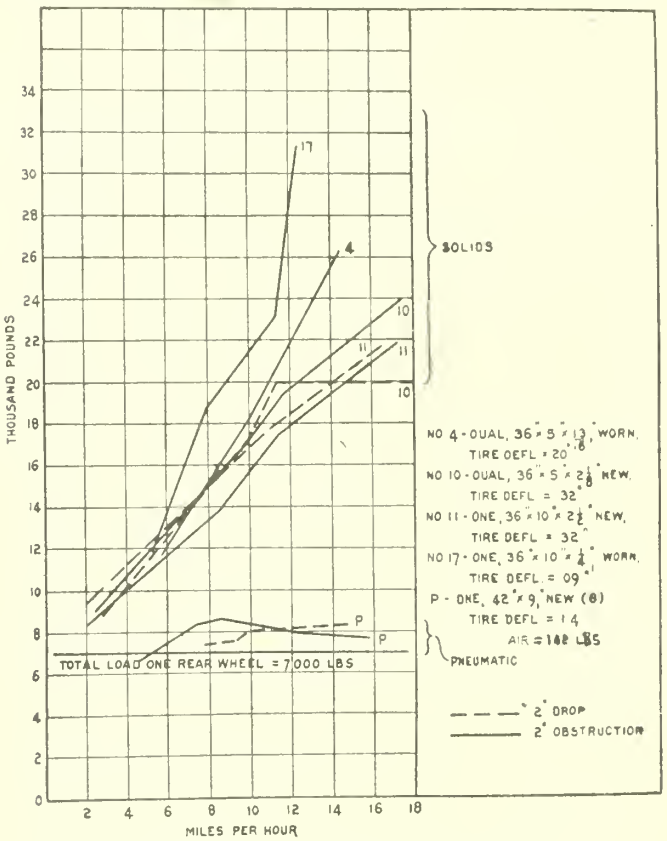

THOUSAND POUNDS
MILES PER HOUR
SOLIDS
17
4
10
11
11
10
P
P
TOTAL LOAD ONE REAR WHEEL = 7,000 LBS
NO 4 - DUAL, 36" × 5" × 1 3/8" WORN.
TIRE DEFL = 20"
NO 10 - DUAL, 36" × 5" × 2 1/8" NEW.
TIRE DEFL = 32"
NO 11 - ONE, 36" × 10" × 2 1/2" NEW.
TIRE DEFL = 32"
NO 17 - ONE, 36" × 10" × 1 1/2" WORN.
TIRE DEFL = 09"
P - ONE, 42" × 9" NEW (8)
TIRE DEFL = 14
AIR = 100 LBS
PNEUMATIC
2" DROP
2" OBSTRUCTION

FIG. 8.—COMPARISON OF TIRES (TRUCK 3½-TON P; LOAD, 4½ TONS (UNSPRUNG WEIGHT), MG., 1,300 LBS.).

given time depends upon the ratio of the spring pressure (including gravity) and the unsprung weight. These two factors can not be separated, because of the influence of the inertia of the unsprung weight. With the same spring pressure a higher velocity will be imparted to a light unsprung weight than to a heavy unsprung weight; also, for any given unsprung weight the greater the spring pressure the greater will be the downward velocity. But when the final value of the force of impact is considered then the factor of unsprung weight enters a second time. For having obtained the deceleration value, as a function of the unsprung weight, spring pressure, and the time required to change the velocity to zero, then the impact force

is the product of this value multiplied by the unsprung weight. Therefore, the greater the spring pressure with a given unsprung weight the greater will be the force of impact. Also, with any given spring and loading condition, the greater the unsprung weight the greater will be the impact.

In the *upward* movement of the wheel as a result of striking an obstruction or irregularity, the initial vertical

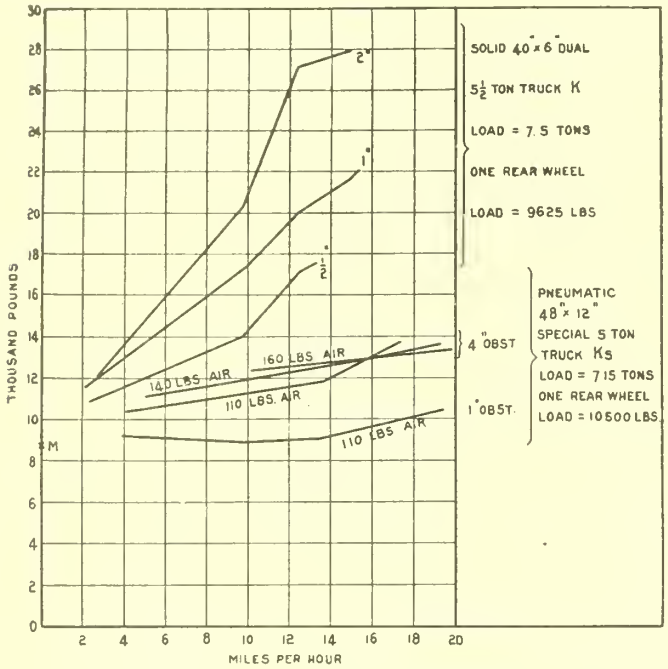


FIG. 9.—COMPARISON OF SOLID AND PNEUMATIC TIRES (TWO TRUCKS APPROXIMATELY THE SAME).

velocity is zero; its maximum velocity and acceleration are dependent upon tire deflection, the slope of the approach, and the horizontal speed of the truck. The value of the force in this case, equals the mass of the unsprung weight multiplied by the vertical acceleration, plus the spring pressure during impact. When the wheel starts downward again if it has left the road surface, the spring pressure acts to increase the impact as explained in the preceding paragraph. It should also be understood that the less the deflection of the tire the greater will be the vertical movement and acceleration; while a soft cushion or a pneumatic tire may so deform or deflect as to absorb more of the vertical movement and thus reduce the acceleration.

The effect on the truck body of the upward movement of the unsprung weight is dependent upon the vertical velocity and acceleration, the spring stiffness, and the load carried. As the weight moves upward it does work by compressing the spring and lifting the body. If very stiff the spring transmits to the body a large part of the force as an impact; resulting in a series of severe vibrations. The amount of energy delivered to the spring may be minimized in any particular truck by reducing the vertical velocity and acceleration, which is most certainly accomplished by slower truck speeds, or by using pneumatic instead of solid tires. All impacts are very much reduced by using good solid tires which have at least a 2-inch thickness of rubber at the tread, instead of old or badly worn tires which have less than 1 inch of rubber thickness. In the design of the truck any reduction of the unsprung weight, or distribution of it to two rear axles instead of one will tend to reduce the upward force against the spring.

EXPERIMENTAL RESULTS.

For the purposes of the tests which have been made a special runway of concrete was constructed, as shown in figure 4. This runway is so designed that the height of the head of the plunger B is flush with the road surface. The "obstruction" tests are made at this place by bolting to the plunger head a strip of hardwood 4 inches wide and 16 inches long, using thicknesses of $\frac{1}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in., 1 in., 2 in., 3 in., and in the case of pneumatic tires, 4 inches.

The "drop" tests are made at the drop-off edge E, the plunger beyond and in the lower pit being so placed that the plunger head A may be elevated to give "drop" distances varying from 0 to 3 inches. The plunger may also be moved away from the edge E any distance to receive the blow of the wheel as it jumps varying distances depending upon the speed of the truck. A $\frac{1}{2}$-inch copper cylinder, heretofore mentioned, is placed under each plunger as shown. By this preparation it is easy to secure the data from both types of tests during one run or passage of the truck.

The impact of only the left rear wheel is measured. A bridge is placed over each plunger head to protect it from the front wheel. As this wheel passes, the bridge is jerked out leaving the plunger head clear to receive the impact of the rear wheel. In the case of the obstruction test, the right wheels (front and rear) do not strike the obstruction. But in the case of the drop test both right and left wheels are caused to drop the same amount.

Truck speeds are determined with a stop watch by noting the time to pass two points which are 30 feet apart. These speed determinations are accurate to a maximum variation of 10 per cent, but from the fact that the results may be influenced more than this amount of variation by the action of the front wheel, this error in speed determination is considered of little consequence.

The indications given by the measurements of the copper cylinders may have a maximum variation of about 5 per cent. This is due to slight variations in the annealing of the copper, to errors in measurement, and to variations in obtaining the equivalent value from the static-load curve.

It has been briefly mentioned above that the introduction of a copper cylinder as a means for measuring

the impact also introduces a cushioning effect which in turn serves to reduce the impact value. A few experiments have been conducted to determine approximately what this cushioning effect may be. Copper cylinders of different diameters all one-half inch in height were used to receive the impact of a constant weight falling the same height in each case. This was also repeated by changing the height of fall. Autographic space-time curves were also taken of these same impacts, without using a copper cylinder. The intermediate sizes of copper cylinders were used to obtain an idea of the progressive variation due to different cushioning effects. Results of these trials are plotted in figure 5. It will be seen that for values of 1-inch drop the1/2-inch copper cylinder indications should be increased 42 per cent and for a 2-inch drop the increase should be 45.6 per cent. By applying such corrections as this for the different heights of drop it is possible to get an idea of the more correct value of the impact force.

The impact values shown on the charts as ordinates are the actual static indications from the 1/2-inch copper cylinder as measured immediately after the test. This is known as the static equivalent, and is plotted as such in all of the charts without corrections of any kind. It is realized that these values are only comparative and are not actual impact values. To arrive at a more nearly actual impact indication, or maximum force value, it will be necessary to correct these static equivalent values by increasing each by the cushioning factor as indicated in figure 5 and multiplying by some factor to allow for the fact that the copper cylinder measures the average impact and not the maximum. The value of this last factor may be from 1.5 to 2, depending upon the equation of the stress-strain diagram. No corrections of this kind have been made in any of the data or charts presented in this paper.

Because of the nature of these experiments no great accuracy has been attempted, and for practical results it is not considered that a high degree of accuracy is necessary. The forces with which we are dealing are very large, and 5 to 10 per cent variation is not considered to be of much importance. To have insisted upon a high degree of accuracy would have delayed the experiments and possibly discouraged further investigation by others.

These tests are planned to show the influence of only the important factors upon the value of the impact force. Not all possible factors are considered, only those having a definite and direct influence and which are more or less easily controlled in the operation of a motor truck, or which may be controlled in the design and equipment.

The speed of the truck is considered to be one of the most important factors. It is the factor which is most spoken of in connection with the operation of a truck, and the one factor against which there are aimed more traffic rules and laws than any other. The determination of its effect upon the value of the impact force is very important. For this reason speed values, in miles per hour, have been made the independent variable in most of the tests.

Trucks of different weights and capacities have been used in the tests. A full tabulation of the weights

TABLE I.—*Showing size, weights, and loadings of trucks.*

Truck.	Rated capacity.	Empty weight.			Unsprung weight.		Distribution of load (cargo only).				Total sprung weight on 1 rear wheel, cargo and truck.	Spring deflection for total sprung weight.	Total load on road from 1 rear wheel.
		Total.	Front.	Rear.	2 rear.	1 rear.	Total tons.	Front axle.	Rear axle.	Per cent load on rear axle.			
	Tons.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*		*Pounds.*		*Pounds.*
W	1¼	6,320	2,250	4,070	2,030	1,065	0	0	0	0	970	.....	2,055
W	1½	6,320	2,250	4,070	2,030	1,065	1½	200	2,880	90	2,410	.....	3,475
W	1½	6,320	2,250	4,070	2,030	1,065	2¼	280	4,410	98	3,175	.....	4,240
A	2	7,800	3,300	4,500	2,000	1,000	0	0	0	0	1,250	1.02	2,250
A	2	7,800	3,300	4,500	2,000	1,000	2	−100	4,100	102.5	3,300	2.70	4,300
A	2	7,800	3,300	4,500	2,000	1,000	3	400	5,600	93.5	3,900	3.19	4,900
A	5	9,850	3,900	5,950	3,900	1,950	0	0	0	0	1,050	.38	3,000
A	5	9,850	3,900	5,950	3,900	1,950	5	50	9,950	100	5,950	2.12	7,900
A	5	9,850	3,900	5,950	3,900	1,950	7½	0	15,150	100	8,650	3.09	10,600
P	3–3½	9,500	3,800	5,700	3,400	1,700	0	0	0	0	1,150	.48	2,850
P	3–3½	9,500	3,800	5,700	3,400	1,700	2½	400	4,600	92	3,450	1.44	5,150
P	3–3½	9,500	3,800	5,700	3,400	1,700	4½	700	8,300	92	5,300	2.25	7,000
B	3	11,370	4,520	6,850	3,675	1,837	0	0	0	0	1,588	.74	3,425
B	3	11,370	4,520	6,850	3,675	1,837	3.6	580	6,620	92	4,900	2.62	6,735
B	3	11,370	4,520	6,850	3,675	1,837	5	980	9,020	90	6,100	3.63	7,935
Ka	5½	11,800	5,300	6,500	2,000	1,000	0	0	0	0	2,250	1.12	3,250
Ka	5½	11,800	5,300	6,500	2,000	1,000	5	540	9,620	95	7,060	3.73	8,060
Ka	5½	11,800	5,300	6,500	2,000	1,000	7½	900	14,650	94	9,575	5.12	10,575
Kc	7½	13,600	5,240	8,380	3,000	1,500	0	0	0	0	2,695	1.08	4,195
Kc	7½	13,600	5,240	8,380	3,000	1,500	3½	310	6,940	104	6,200	2.70	7,700
Kc	7½	13,600	5,240	8,380	3,000	1,500	8½	360	16,720	97.5	11,000	4.78	12,500
Ks	5	13,600	5,860	7,740	2,260	1,130	0	0	0	0	2,740	.....	3,870
Ks	5	13,600	5,860	7,740	2,260	1,130	6.4	1,050	10,680	92	8,080	.....	9,215
Ks	5	13,600	5,860	7,740	2,260	1,130	7.15	1,020	13,280	93	9,380	.....	10,510
Kb	5½	9,800	4,900	4,900	2,600	1,300	0	0	0	0	1,600	.53	2,900
Kb	5½	9,800	4,900	4,900	2,600	1,300	5	650	9,350	93.5	5,800	1.93	7,100
Kb	5½	9,800	4,900	4,900	2,600	1,300	7½	650	14,350	95.6	8,800	2.93	10,100
G	5	12,700	.....	.....	[2]3,000	[1]1,500	5	.....	.....	.....	[1]7,980	1.75	[1]9,480
G	.....	.....	.....	.....	[2]3,000	[1]1,500	7½	.....	.....	.....	[1]10,280	2.62	[1]11,775

[1] Two wheels.

[2] Four wheels.

TABLE II.—*Data referring to the graphical charts.*

Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires.			Springs.		Type of test.
						No.	Kind.	Deformation due to wheel load.	No.	Deflection due to sprung weight.	
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
1	F	1	1	1,175	375	7	Solid	0.11		1.63	Drop-stationary.
2	F	1	1	1,175	375	7	do	.11		1.63	Obstruction.
3	F	1	1	1,175	375		Cushion	.33		1.63	Do.
4	W	1½	0	970	1,065	5	Solid	.13			Drop.
5	W	1½	1½	2,410	1,065	5	do	.15			Do.
6	W	1½	2½	3,175	1,065	5	do	.23			Do.
7	W	1½	0	970	1,065	5	do	.13			Obstruction.
8	W	1½	1½	2,410	1,065	5	do	.15			Do.
9	W	1½	2½	3,175	1,065	5	do	.23			Do.
10	A	2	3	3,900	1,000	22	Pneumatic	1.05	E	3.19	Drop.
11	A	2	2	3,300	1,000	22	do	.95	E	2.70	Do.
12	A	2	3	3,900	1,000	22	do	1.05	E	3.19	Obstruction.
13	A	2	2	3,300	1,000	22	do	.95	E	2.70	Do.
14	A	2	2	3,300	1,000	21	do	1.05	E	2.70	Drop.
15	A	2	3	3,900	1,000	21	do	1.15	E	3.19	Do.
16	A	2	2	3,300	1,000	21	do	1.05	E	2.70	Obstruction.
17	A	2	3	3,900	1,000	21	do	1.15	E	2.70	Do.
18	A	2	3	3,900	1,000	22	do	1.05	E	3.19	Drop.
19	A	2	3	3,900	1,000	22	do	1.05	E	3.19	Obstruction.
20	A	2	0	1,250	1,000	8	Cushion	.39	E	1.02	Drop.
21	A	2	2	3,300	1,000	8	do	.57	E	2.70	Do.
22	A	2	3	3,900	1,000	8	do	.62	E	3.19	Do.
23	A	2	2	3,300	1,000	8	do	.57	E	2.70	Obstruction.
24	A	2	3	3,900	1,000	8	do	.62	E	3.19	Do.
25	A	2	2	3,300	1,000	9	Solid	.27	E	2.70	Drop.
26	A	2	3	3,900	1,000	9	do	.30	E	3.19	Do.
27	A	2	2	3,300	1,000	9	do	.27	E	2.70	Obstruction.
28	A	2	3	3,900	1,000	9	do	.30	E	3.19	Do.
29	A	2	3	3,900	1,000	12	do	.32	E	3.19	Do.
30	A	2	2	3,300	1,000	12	do	.30	E	2.70	Do.
31	A	2	2	3,300	1,000	12	do	.30	E	2.70	Drop.
32	P	3–3½	2½	3,450	1,700		Pneumatic	1.18	D	1.44	Do.
33	P	3–3½	4½	5,300	1,700		do	1.40	D	2.20	Do.
34	P	3–3½	0	1,150	1,700	4	Solid	.12	D	.48	Do.
35	P	3–3½	2½	3,450	1,700	4	do	.17	D	1.44	Do.
36	P	3–3½	4½	5,300	1,700	4	do	.20	D	2.20	Do.
37	P	3–3½	2½	3,450	1,700	10	do	.26	D	1.44	Do.
38	P	3–3½	4½	5,300	1,700	10	do	.32	D	2.20	Do.
39	P	3–3½	0	1,150	1,700	10	do	.18	D	.48	Do.
40	P	3–3½	2½	3,450	1,700	10	do	.26	D	1.44	Do.
41	P	3–3½	4½	5,300	1,700	10	do	.32	D	2.20	Do.
42	P	3–3½	0	1,150	1,700	10	do	.18	D	.48	Obstruction.
43	P	3–3½	2½	3,450	1,700	10	do	.26	D	1.44	Do.
44	P	3–3½	4½	5,300	1,700	10	do	.32	D	2.20	Do.
45	P	3–3½	0	1,150	1,700	11	do	.17	D	.48	Drop.
46	P	3–3½	2½	3,450	1,700	11	do	.26	D	1.44	Do.
47	P	3–3½	4½	5,300	1,700	11	do	.32	D	2.20	Do.
48	P	3–3½	0	1,150	1,700	11	do	.17	D	.48	Obstruction.
49	P	3–3½	2½	3,450	1,700	11	do	.26	D	1.44	Do.
50	P	3–3½	4½	5,300	1,700	11	do	.32	D	2.20	Do.
51	P	3–3½	0	1,150	1,700	17	do	.05	D	.48	Drop.
52	P	3–3½	2½	3,450	1,700	17	do	.08	D	1.44	Do.
53	P	3–3½	4½	5,300	1,700	17	do	.09	D	2.20	Do.
54	P	3–3½	0	1,150	1,700	17	do	.05	D	.48	Obstruction.
55	P	3–3½	2½	3,450	1,700	17	do	.08	D	1.44	Do.
56	P	3–3½	4½	5,300	1,700	17	do	.09	D	2.20	Do.
57	P	3–3½	0	1,150	1,700	18	do	.05	D	.48	Do.
58	P	3–3½	0	1,150	1,700	18	do	.05	D	.48	Drop.
59	B	3	0	1,388	1,837		do		A	.74	Do.
60	B	3	3.6	4,700	1,837		do		A	2.62	Do.
61	B	3	5	5,900	1,837		do		A	3.62	Do.
62	B	3	0	1,388	1,837		do		A	.74	Obstruction.
63	B	3	3.6	4,700	1,837		do		A	2.62	Do.
64	B	3	5	5,900	1,837		do		A	3.62	Do.
65	A	5	5	5,950	1,950	13	do	.15	F	2.12	Drop.
66	A	5	7½	8,650	1,950	13	do	.18	F	3.09	Do.
67	A	5	5	5,950	1,950	13	do	.15	F	2.12	Obstruction.
68	A	5	7½	8,650	1,950	13	do	.18	F	3.09	Do.
69	A	5	0	1,050	1,950	14	do	.13	F	.38	Drop.
70	A	5	5	5,950	1,950	14	do	.26	F	2.12	Do.
71	A	5	7½	8,650	1,950	14	do	.31	F	3.09	Do.
72	A	5	0	1,050	1,950	14	do	.13	F	.38	Obstruction.
73	A	5	5	5,950	1,950	14	do	.26	F	2.12	Do.
74	A	5	7½	8,650	1,950	14	do	.31	F	3.09	Do.
75	A	5	0	1,050	1,950	15	do	.19	F	.38	Drop.
76	A	5	5	5,950	1,950	15	do	.38	F	2.12	Do.
77	A	5	7½	8,650	1,950	15	do	.45	F	3.09	Do.
78	A	5	0	1,050	1,950	15	do	.19	F	.38	Obstruction.
79	A	5	5	5,950	1,950	15	do	.38	F	2.12	Do.
80	A	5	7½	8,650	1,950	15	do	.45	F	3.09	Do.
81	A	5	0	1,050	1,950	24	do	.18	F	.38	Drop.
82	A	5	5	5,950	1,950	24	do	.36	F	2.12	Do.
83	A	5	7½	8,650	1,950	24	do	.43	F	3.09	Do.
84	A	5	0	1,050	1,950	24	do	.18	F	.38	Obstruction.
85	A	5	5	5,950	1,950	24	do	.36	F	2.12	Do.
86	A	5	7½	8,650	1,950	24	do	.43	F	3.09	Do.
87	A	5	0	1,050	1,950	25	do	.08	F	.38	Drop.
88	A	5	5	5,950	1,950	25	do	.16	F	2.12	Do.
89	A	5	7½	8,650	1,950	25	do	.19	F	3.09	Do.
90	A	5	4.8	5,150	1,950	25	do	.15	F	1.84	Do.
91	A	5	6.7	8,150	1,950	25	do	.18	F	2.90	Do.
92	A	5	0	1,050	1,950	25	do	.08	F	.38	Obstruction.
93	A	5	5	5,950	1,950	25	do	.16	F	2.12	Do.
94	A	5	7½	8,650	1,950	25	do	.19	F	3.09	Do.
95	A	5	4.8	5,150	1,950	25	do	.15	F	1.84	Do.
96	A	5	6.7	8,150	1,950	25	do	.18	F	2.90	Do.
97	Ka	5½	5	7,060	1,000	2	do	.23	B	3.73	Iron obstruction.
98	Ka	5½	5	7,060	1,000	2	do	.23	B	3.73	Drop.
99	Ka	5½	7¼	9,575	1,000	2	do	.28	B	5.12	Do.

TABLE II.—*Data referring to the graphical chart*—Continued.

Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires.			Springs.		Type of test.
						No.	Kind.	Deformation due to wheel load.	No.	Deflection due to sprung weight.	
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
100	Ka	5½	0	2,250	1,000	2	Solid	0.15	B	1.12	Obstruction.
101	Ka	5½	5	7,060	1,000	2	do	.23	B	3.73	Do.
102	Ka	5½	7¾	9,575	1,000	2	do	.28	B	5.12	Do.
103	Kb	5½	0	1,600	1,300	16	do	.15	G	.53	Drop.
104	Kb	5½	5	5,800	1,300	16	do	.28	G	1.93	Do.
105	Kb	5½	7½	8,800	1,300	16	do	.35	G	2.93	Do.
106	Kb	5½	0	1,600	1,300	16	do	.15	G	.53	Obstruction.
107	Kb	5½	5	5,800	1,300	16	do	.28	G	1.93	Do.
108	Kb	5½	7½	8,800	1,300	16	do	.35	G	2.93	Do.
109	Kb	5½	0	1,600	1,300	24	do	.18	G	.53	Drop.
110	Kb	5½	5	5,800	1,300	24	do	.33	G	1.93	Do.
111	Kb	5½	7½	8,800	1,300	24	do	.42	G	2.93	Do.
112	Kb	5½	0	1,600	1,300	24	do	.18	G	.53	Obstruction.
113	Kb	5½	5	5,800	1,300	24	do	.35	G	1.93	Do.
114	Kb	5½	7½	8,800	1,300	24	do	.42	G	2.93	Do.
115	Kb	5½	0	1,600	1,300	25	do	.08	G	.53	Drop.
116	Kb	5½	5	5,800	1,300	25	do	.15	G	1.93	Do.
117	Kb	5½	7½	8,800	1,300	25	do	.18	G	2.93	Do.
118	Kb	5½	0	1,600	1,300	25	do	.08	G	.53	Obstruction.
119	Kb	5½	5	5,800	1,300	25	do	.15	G	1.93	Do.
120	Kb	5½	7½	8,800	1,300	25	do	.18	G	2.93	Do.
121	Kc	7½	0	2,700	1,500	1	do	.30	C	1.08	Drop.
122	Kc	7½	3½	6,200	1,500	1	do	.48	C	2.70	Do.
123	Kc	7½	8½	11,000	1,500	1	do	.60	C	4.78	Do.
124	Kc	7½	0	2,700	1,500	1	do	.30	C	1.08	Obstruction.
125	Kc	7½	3½	6,200	1,500	1	do	.48	C	2.70	Do.
126	Kc	7½	8½	11,000	1,500	1	do	.60	C	4.78	Do.
127	Ks	5	0	2,740	1,130		Pneumatic				Do.
128	Ks	5	6.4	8,080	1,130		do				Do.
129	Ks	5	7.15	9,380	1,130		do				Do.
130	G	5	5	[1] 7,980	[1] 1,500		do			1.75	Drop.
131	G	5	7½	[1] 10,280	[1] 1,500		do			2.62	Do.
132	G	5	5	[1] 7,980	[1] 1,500		do			1.75	Obstruction.
133	G	5	7½	[1] 10,280	[1] 1,500		do			2.62	Do.

and equipment of the trucks used is shown in Table I. Some of these trucks have comparatively heavy unsprung parts and some have light unsprung parts. The effect of this factor was especially studied in the tests upon two trucks of the same capacity under different loadings and speeds, each truck being equipped with the same set of tires.

Tire equipment was considered to be a very important factor. As far as possible, each truck was tested, at different speeds and loadings, with several kinds and conditions of tires.

To get a definite idea of the effect of the height of fall, or of the height of an obstruction or irregularity in a road surface, this factor was used as one of the variables in most of the tests.

The experimental results obtained during the conduct of these tests are plotted in Charts Nos. 1 to 133, inclusive. The data as plotted on these charts represent the average of two or three trials, and in the case of wide variation from the supposed position of the point on the curve additional trials were made. In several cases the plotted points on these curves seem to be more or less out of position to give uniform or relative results, but from successive trials and observations during the test it was noted that certain oscillations set up by the front wheel striking the obstruction are sufficient to very materially change the impact of the rear wheel.

The index to these charts is given by corresponding numbers at the bottom of each page, and the data for all charts are repeated in Table II. The points on the vertical axis of each curve marked Mg and mg are respectively the values of the sprung weight and of the unsprung weight. This is shown on each chart for the purpose of comparing the impact values with the load values.

No attempt will be made to explain all the variations which may be noticed on the charts. The data are presented complete for the purpose of affording an opportunity to make such extended study as any one may desire.

The results presented in Charts Nos. 130 to 133, inclusive, are for a very special truck constructed with two rear axles, making what may be called a six-wheel truck. This truck was equipped with pneumatic tires; and power was applied to each of the four rear wheels. This construction serves to distribute the weights to four wheels at the rear of the truck instead of two wheels as in the ordinary truck. The impact results, as shown on these charts represent the combined impacts received from the two left rear wheels. It should be noticed in this particular case that the impact is practically constant for speeds between 10 and 25 miles per hour and that the impact value was less than the total load on two rear wheels.

Charts Nos. 127 to 129, inclusive, show the variation of the impact due to different air pressures in pneumatic tires.

Spring dimensions and characteristics are shown in figure 3, and Table III. It should be noticed that the "load-deflection" curve in each case is practically a straight line. These data should aid in a further study of the impact results.

TABLE III.—*Showing spring characteristics of the various trucks used in the tests. (See Figure 3.)*

Curve.	Truck.	A	B	D	Number of leaves.	Width.	Stiffness.
	Tons.	*Inches.*	*Inches.*	*Inches.*		*Inches.*	*Pounds per inch.*
A	3 B	57½	6½	.....	17	4	1,625
B	5½ Ka	52	6½	7¼	17	4	2,000
C	7½ Kc	50½	6¾	7	17	4	2,300
D	3 P	45½	5¼	7	12	3	2,400
E	2 A	52⅝	4½	7	12	3	1,230
F	5 A	47⅝	6½	8	16	3	2,800
G	5½ Kb	52	6¼	6½	17	4	3,000

Tire dimensions and deformations are shown in figure 6. For each tire a curve is shown which gives the deflection or deformation under different loads.

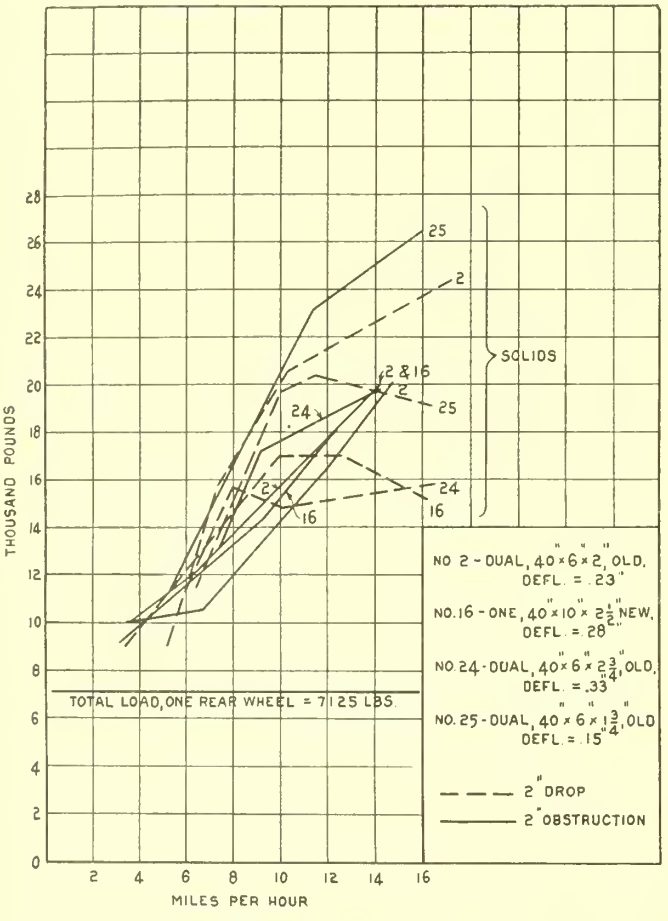

THOUSAND POUNDS
MILES PER HOUR
SOLIDS
25
2
2 & 16
24
16
TOTAL LOAD, ONE REAR WHEEL = 7125 LBS.
NO 2 - DUAL, 40"×6"×2", OLD. DEFL. = .23"
NO. 16 - ONE, 40"×10"×2½" NEW. DEFL. = .28"
NO 24 - DUAL, 40"×6"×2¾", OLD. DEFL. = .33"
NO. 25 - DUAL, 40"×6"×1¾", OLD DEFL. = .15"
2" DROP
2" OBSTRUCTION

FIG. 10.—COMPARISON OF TIRES (TRUCK 5-TON K; LOAD, 5 TONS; (UNSPRUNG WEIGHT), mg., 1,300 LBS.).

No attempt is made to take into account the variation in rubber composition, except as is shown by the deformation.

After securing and studying results as shown in Charts Nos. 1 to 133, inclusive, many interesting and important comparisons present themselves. No attempts will be made at this time to analyze all possible comparisons between the results shown on the charts. A few of the important features and indications are shown in figures 7 to 12, inclusive.

Figure 7 shows an important comparison of the effect of the tire equipment upon the value of the impact. The truck used in this comparison was of 2-ton capacity, carrying a 2-ton load. Four different tires were used and a complete series of tests was run with each, using in each case the speed as the independent variable. The comparison is shown with both the drop and the obstruction test. To draw attention to the obstruction test only, it is noticed that the impact value (the ordinate) shows a considerable change with only a slight change in the tire deflection. The impact value, with all conditions the same except the tire, is the greatest for the solid rubber tires and the smallest for the pneumatic tire, the cushion tire giving an intermediate value. At low speed the difference is not so great. At a speed of 17½ miles per hour the pneumatic tire gives an impact value of only 1.75 times the rear wheel pressure on the road surface, the cushion tire over three times, and the solids 4.3 to 5.1 times. In this particular case, the cushion tire gives an impact value of 63 per cent of the solid tire average, and the pneumatic only 36 per cent. It should also be noticed that for the pneumatic tire the impact value increases only very slightly with the increase of speed.

Figure 8 shows also a comparison of the effect of tire equipment. The truck used in this case was of 3½-ton capacity, loaded with 4½ tons, the unsprung weight being equal to 1,300 pounds. The total load at one rear wheel was 7,000 pounds. Here, it should be noticed that with pneumatic tire equipment the impact force was only 15 per cent greater than the actual wheel load. The four different solid tires which were used in this series show very clearly the effect of the condition of the tire. Tire No. 17 gave some very high impact values even at 12 miles per hour. This tire was badly worn, having a thickness of only one-fourth inch above the rim. The other solid tires gave impact values somewhat in proportion to their deflection or condition. The results as shown by tires Nos. 10 and 11 indicate the usual impact values that may be expected with good solid tire equipment, while the results shown by the use of tires Nos. 4 and 17 show the increase or extreme values that may be expected from the same truck when the tires are in a badly worn condition.

Figure 9 is also a comparison between the effects of solid and pneumatic tires. The truck used in this case was of 5½-ton capacity, loaded with 7½ tons. This figure is intended to show the very great cushioning effect of pneumatic tires in comparison with solid tires. In this case a 4-inch obstruction was used during the test with the pneumatic tires, and the resulting effect was very much less than when using a solid tire on ½-inch, or 1-inch, or 2-inch obstruction. The figure also shows the effect of the air pressure in the pneumatic tires upon the value of the impact force.

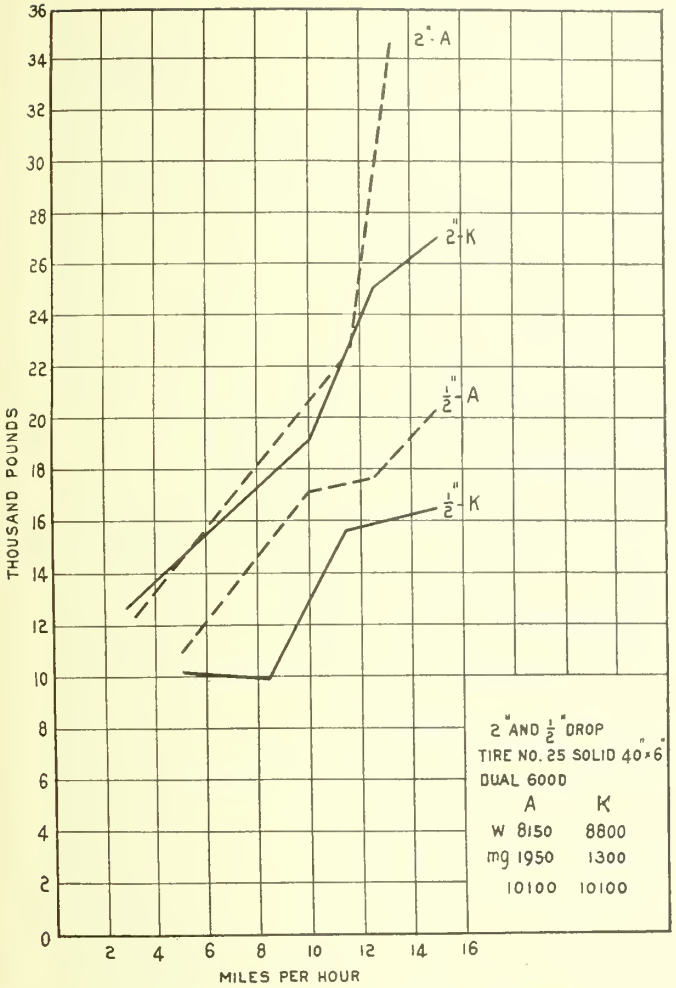


FIG. 11.—COMPARISON OF TRUCKS VS. SPEED.

Figure 10 shows also a comparison of tires. This shows that in general the magnitude of the impact force is dependent upon the condition and deflection of the tire. It shows, as did figure 8, the wide variation in impact values that may be expected from the same truck equipped with tires of different conditions.

Figure 11 shows a comparison between trucks. Two 5½-ton trucks were used in this case and each was loaded so that the total rear wheel load was the same in each case. Truck A had an unsprung weight of 1,950 pounds and truck K had an unsprung weight of 1,300 pounds. Both trucks were equipped with the same set of tires. The purpose of this comparison is to show the effect of unsprung weight upon the impact value. It is very clear that the truck having the lighter unsprung weight produced the smaller impact values under the conditions of this test.

Figure 12. The purpose of this chart is to show the possible impact values which may be obtained by using trucks of different capacities. It is clear that the light truck, W, if run at a sufficient speed, may give impact values as high as a heavy truck, when run at the ordinary truck speeds of 8 to 10 miles per hour. These impact values were all obtained from a 2-inch obstruction. This figure shows that it can not be said that a heavy truck always gives the highest impact values, without stating several qualifying conditions, especially the condition of speed and of tire equipment. This statement refers to impacts only. It should be noted in particular that a light truck running at high speed will produce large impacts only occasionally and never very heavy load pressures; while a heavy truck will produce in addition to impacts a continuous heavy pressure on the road surface.

SUMMARY OF INDICATIONS.

The results presented here must not be considered as final. The investigation has not been completed, and will continue under different conditions for some time.

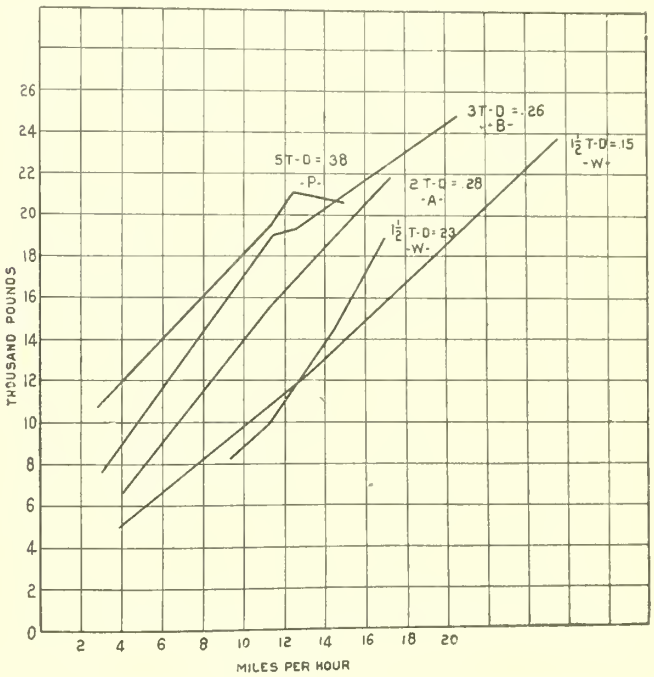


FIG. 12.—COMPARISON OF TRUCKS. (TIRE DEFLECTIONS INDICATED. ALL 2-INCH OBSTRUCTIONS).

It is not the intention in this paper to state final conclusions or to deduce final laws and comparisons. It is, however, thought desirable to state briefly some of the indications toward which these results may point.

The impact value depends very largely upon the tire equipment. The condition of the tire—that is, whether it is new or badly worn—determines the amount of cushioning effect it may offer. The deflection of the tire depends upon its depth and quality, and any condition of the tire which adds to its deflection will, of course, serve to reduce the impact. The actual shape and construction of the tire seem to have considerable influence upon its cushioning effect. No account, however, has been taken of the power-consuming factor of any particular type or shape of tire.

So far as they have been tested, cushion tires seem to offer a decided advantage in reducing the impact. In

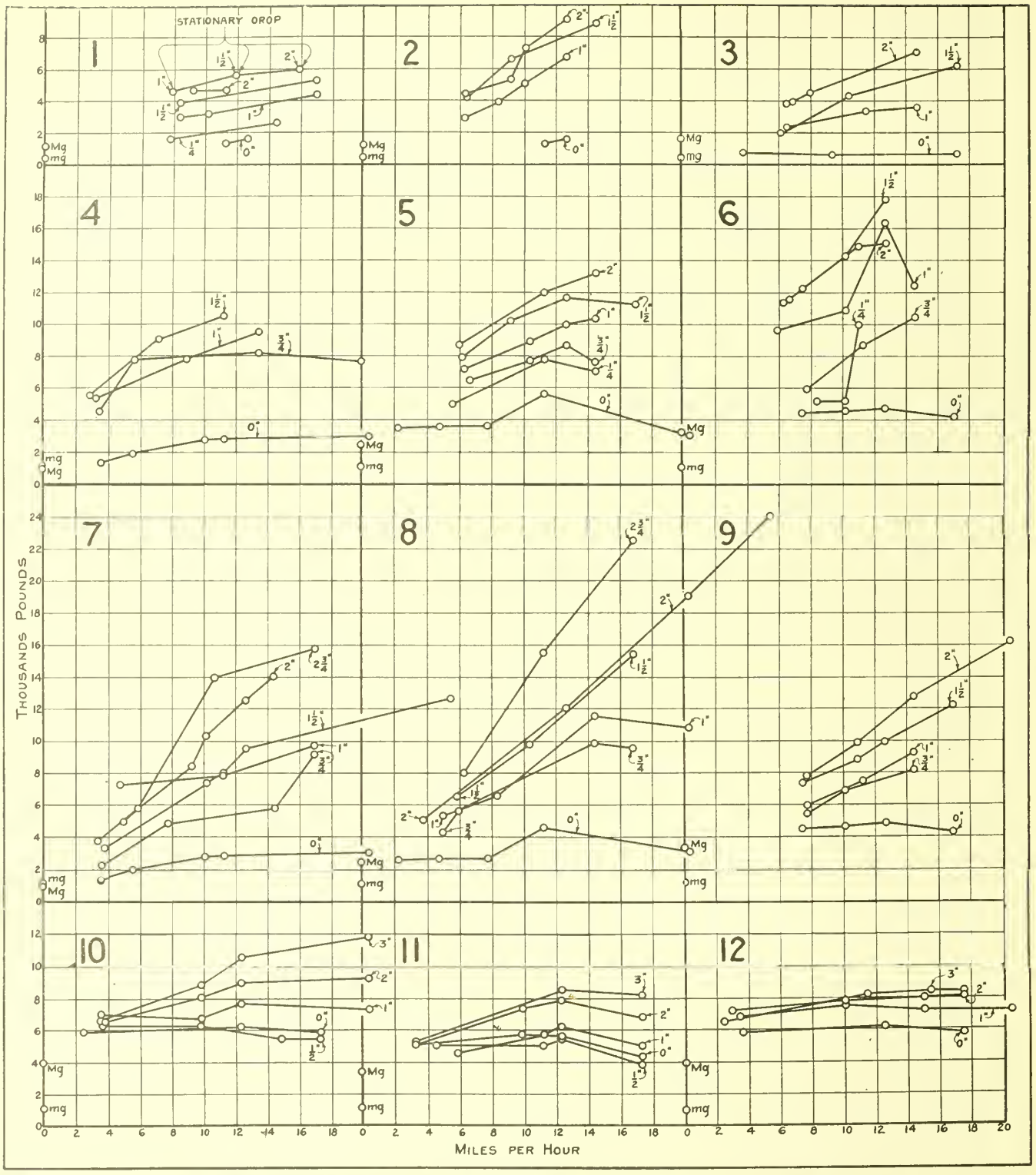


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires.			Springs.		Type of test.
						No.	Kind.	Deformation due to wheel load.	No.	Deflection due to sprung weight.	
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
1	F	1	1	1,175	375	7	Solid	0.11	.....	1.63	Drop-stationary.
2	F	1	1	1,175	375	7	.....do	.11	.....	1.63	Obstruction.
3	F	1	1	1,175	375	.....	Cushion	.33	.....	1.63	Do.
4	W	1½	0	970	1,065	5	Solid	.13	.....	.....	Drop.
5	W	1½	1½	2,410	1,065	5	.....do	.15	.....	.....	Do.
6	W	1½	2¼	3,175	1,065	5	.....do	.23	.....	.....	Do.
7	W	1½	0	970	1,065	5	.....do	.13	.....	.....	Obstruction.
8	W	1½	1½	2,410	1,065	5	.....do	.15	.....	.....	Do.
9	W	1½	2¼	3,175	1,065	5	.....do	.23	.....	.....	Do.
10	A	2	3	3,900	1,000	22	Pneumatic	1.05	E	3.19	Drop.
11	A	2	2	3,300	1,000	22	.....do	.95	E	2.70	Do.
12	A	2	3	3,909	1,000	22	.....do	1.05	E	3.19	Obstruction.

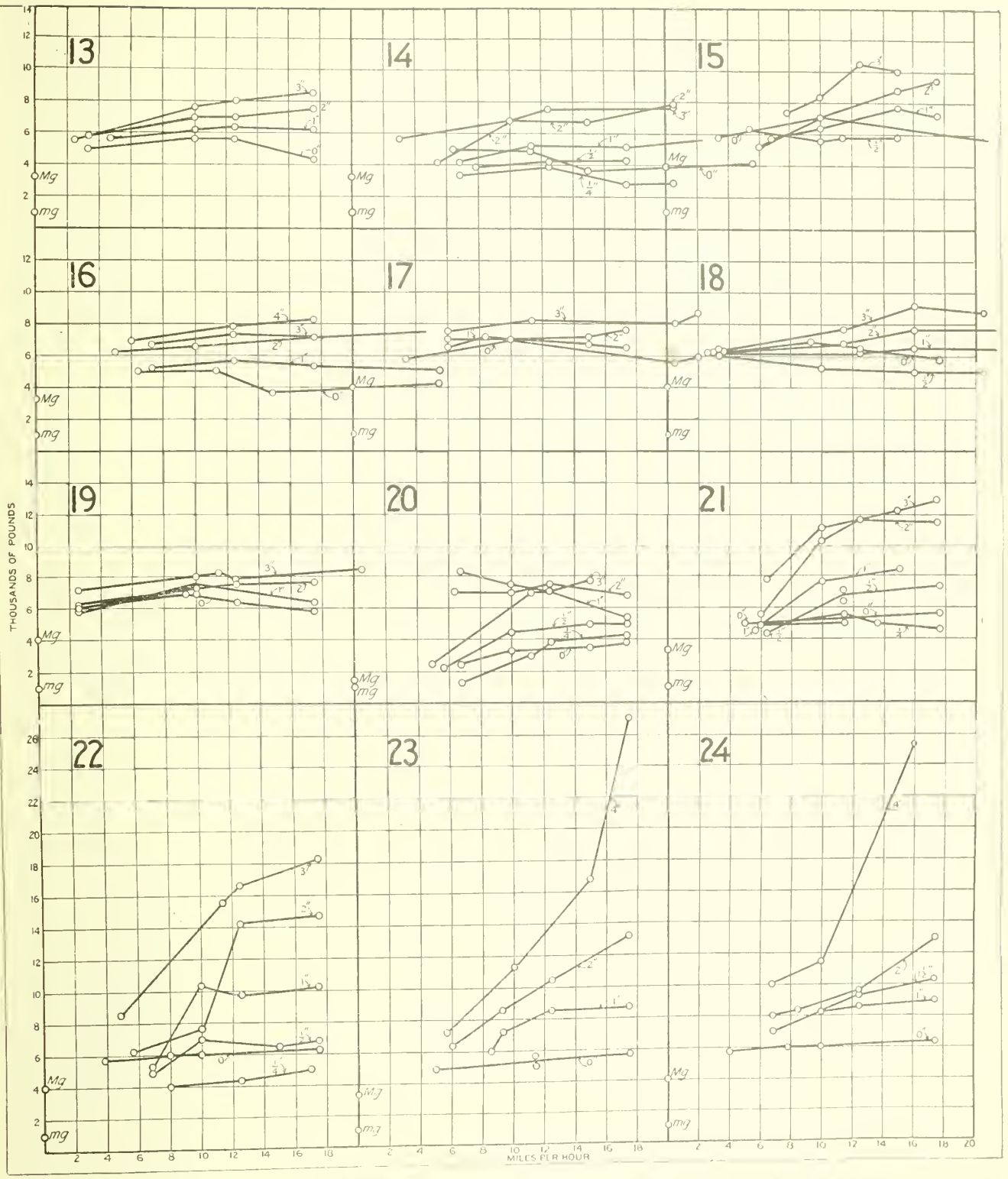


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
13	A	2	2	3,300	1,000	22	Pneumatic	0.95	E	2.70	Obstruction.
14	A	2	2	3,300	1,000	21	do	1.05	E	2.70	Drop.
15	A	2	3	3,900	1,000	21	do	1.15	E	3.19	Do.
16	A	2	2	3,300	1,000	21	do	1.05	E	2.70	Obstruction.
17	A	2	3	3,900	1,000	21	do	1.15	E	2.70	Do.
18	A	2	3	3,900	1,000	22	do	1.05	E	3.19	Drop.
19	A	2	3	3,900	1,000	22	do	1.05	E	3.19	Obstruction.
20	A	2	0	1,250	1,000	8	Cushion	.39	E	1.02	Drop.
21	A	2	2	3,300	1,000	8	do	.57	E	2.70	Do.
22	A	2	3	3,900	1,000	8	do	.62	E	3.19	Do.
23	A	2	2	3,300	1,000	8	do	.57	E	2.70	Obstruction.
24	A	2	3	3,900	1,000	8	do	.62	E	3.19	Do.

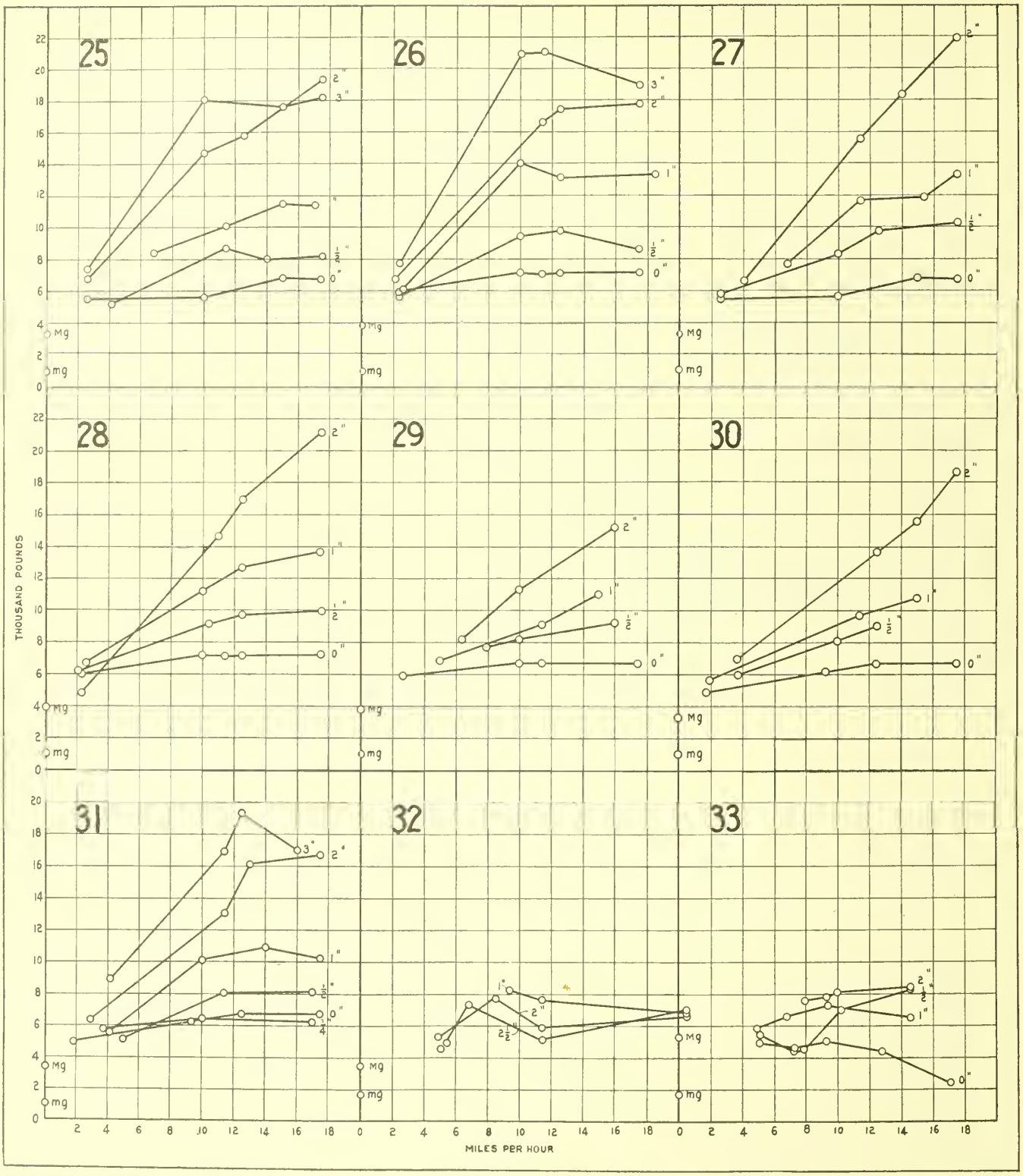


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
25	A	2	2	3,300	1,000	9	Solid	0.27	E	2.70	Drop.
26	A	2	3	3,900	1,000	9	do	.30	E	3.19	Do.
27	A	2	2	3,300	1,000	9	do	.27	E	2.70	Obstruction.
28	A	2	3	3,900	1,000	9	do	.30	E	3.19	Do.
29	A	2	3	3,900	1,000	12	do	.32	E	3.19	Do.
30	A	2	2	3,300	1,000	12	do	.30	E	2.70	Do.
31	A	2	2	3,300	1,000	12	do	.30	E	2.70	Drop.
32	P	3–3½	2½	3,450	1,700	.....	Pneumatic	1.18	D	1.44	Do.
33	P	3–3½	4½	5,300	1,700	.....	do	1.40	D	2.20	Do.

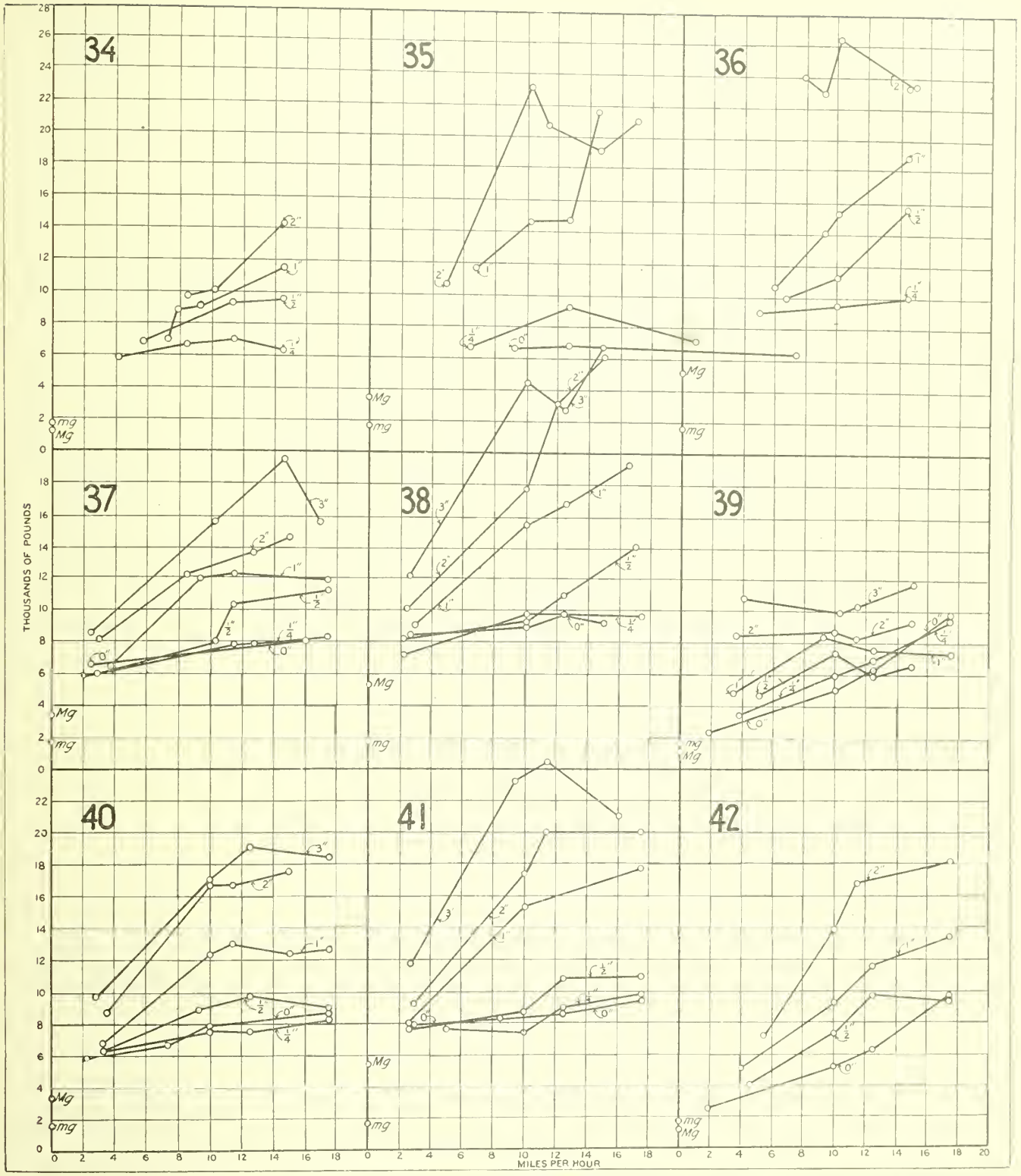


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Springs. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
34	P	3–3½	0	1,150	1,700	4	Solid.	0.12	D	0.48	Drop.
35	P	3–3½	2½	3,450	1,700	4	do.	.17	D	1.44	Do.
36	P	3–3½	4½	5,300	1,700	4	do.	.20	D	2.20	Do.
37	P	3–3½	2½	3,450	1,700	10	do.	.26	D	1.44	Do.
38	P	3–3½	4½	5,300	1,700	10	do.	.32	D	2.20	Do.
39	P	3–3½	0	1,150	1,700	10	do.	.18	D	.48	Do.
40	P	3–3½	2½	3,450	1,700	10	do.	.26	D	1.44	Do.
41	P	3–3½	4½	5,300	1,700	10	do.	.32	D	2.20	Do.
42	P	3–3½	0	1,150	1,700	10	do.	.18	D	.48	Obstruction.

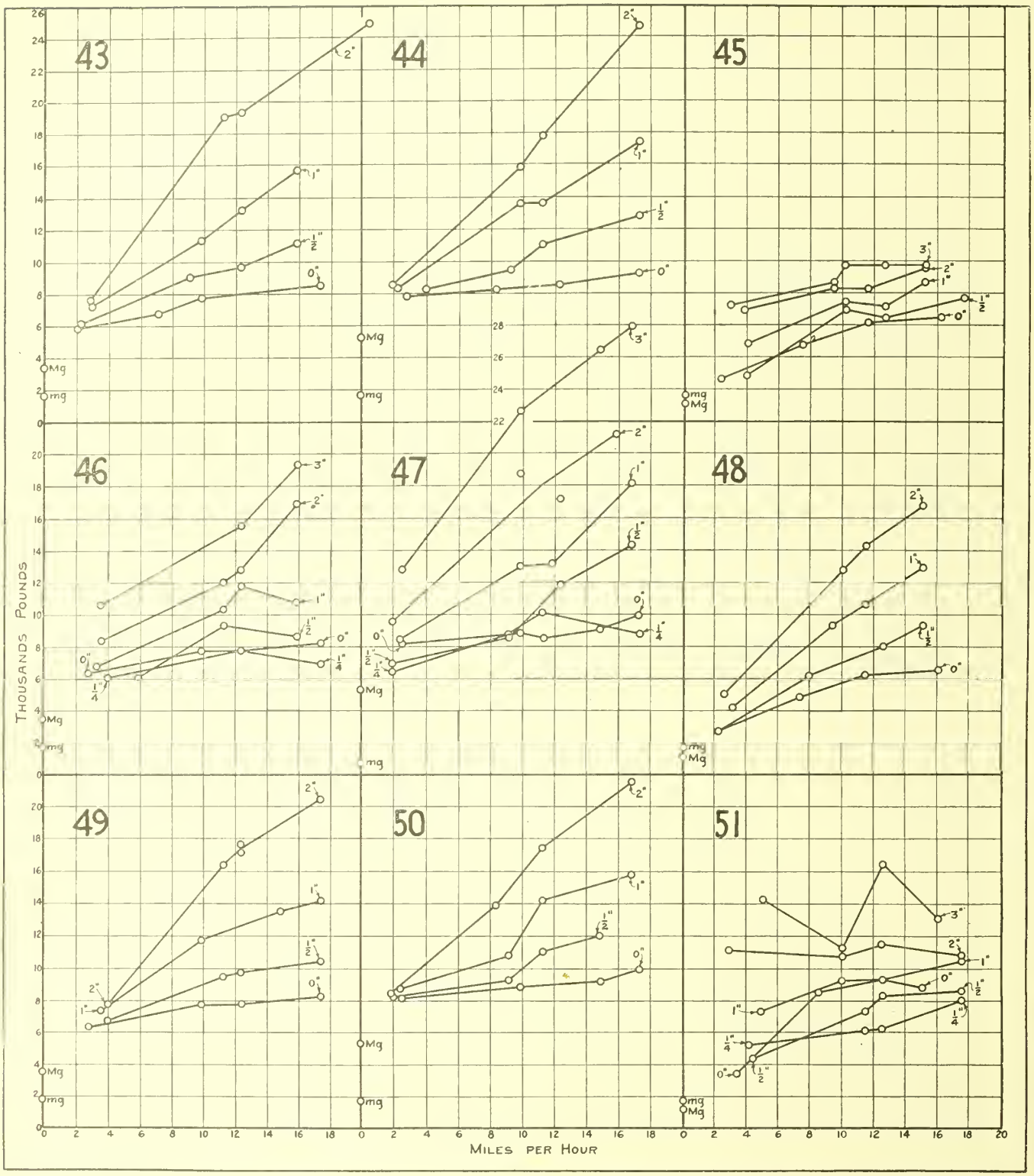


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
43	P	3–3½	2½	3,450	1,700	10	Solid	0.26	D	1.44	Obstruction.
44	P	3–3½	4½	5,300	1,700	10	do	.32	D	2.20	Do.
45	P	3–3½	0	1,150	1,700	11	do	.17	D	.48	Drop.
46	P	3–3½	2½	3,450	1,700	11	do	.26	D	1.44	Do.
47	P	3–3½	4½	5,300	1,700	11	do	.32	D	2.20	Do.
48	P	3–3½	0	1,150	1,700	11	do	.17	D	.48	Obstruction.
49	P	3–3½	2½	3,450	1,700	11	do	.26	D	1.44	Do.
50	P	3–3½	4½	5,300	1,700	11	do	.32	D	2.20	Do.
51	P	3–3½	0	1,150	1,700	17	do	.05	D	.48	Drop.

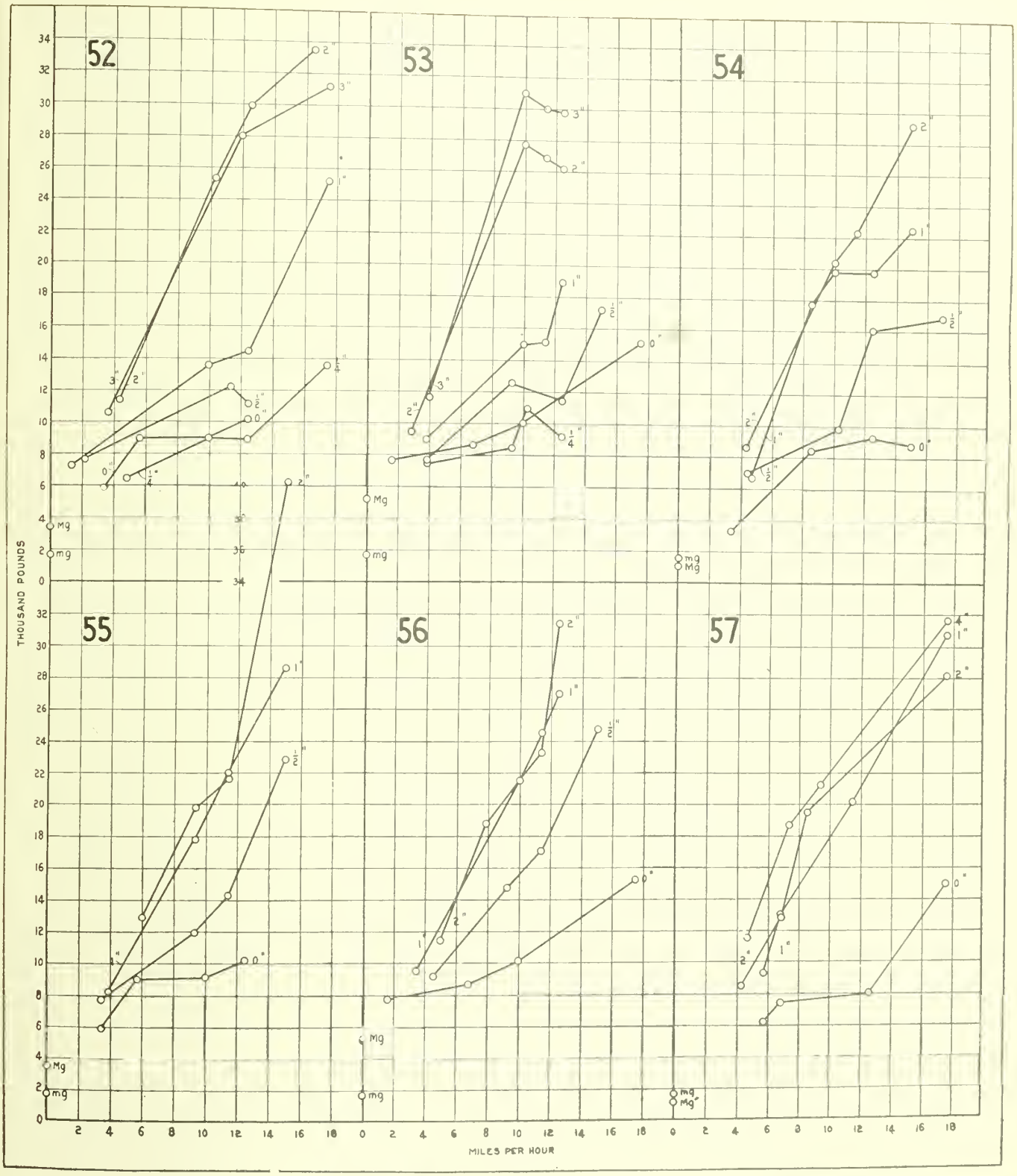


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
52	P	3–3½	2½	3,450	1,700	17	Solid	0.08	D	1.44	Drop.
53	P	3–3½	4½	5,300	1,700	17	do	.09	D	2.20	Do.
54	P	3–3½	0	1,150	1,700	17	do	.05	D	.48	Obstruction.
55	P	3–3½	2½	3,450	1,700	17	do	.08	D	1.44	Do.
56	P	3–3½	4½	5,300	1,700	17	do	.09	D	2.20	Do.
57	P	3–3½	0	1,150	1,700	18	do	.05	D	.48	Do.

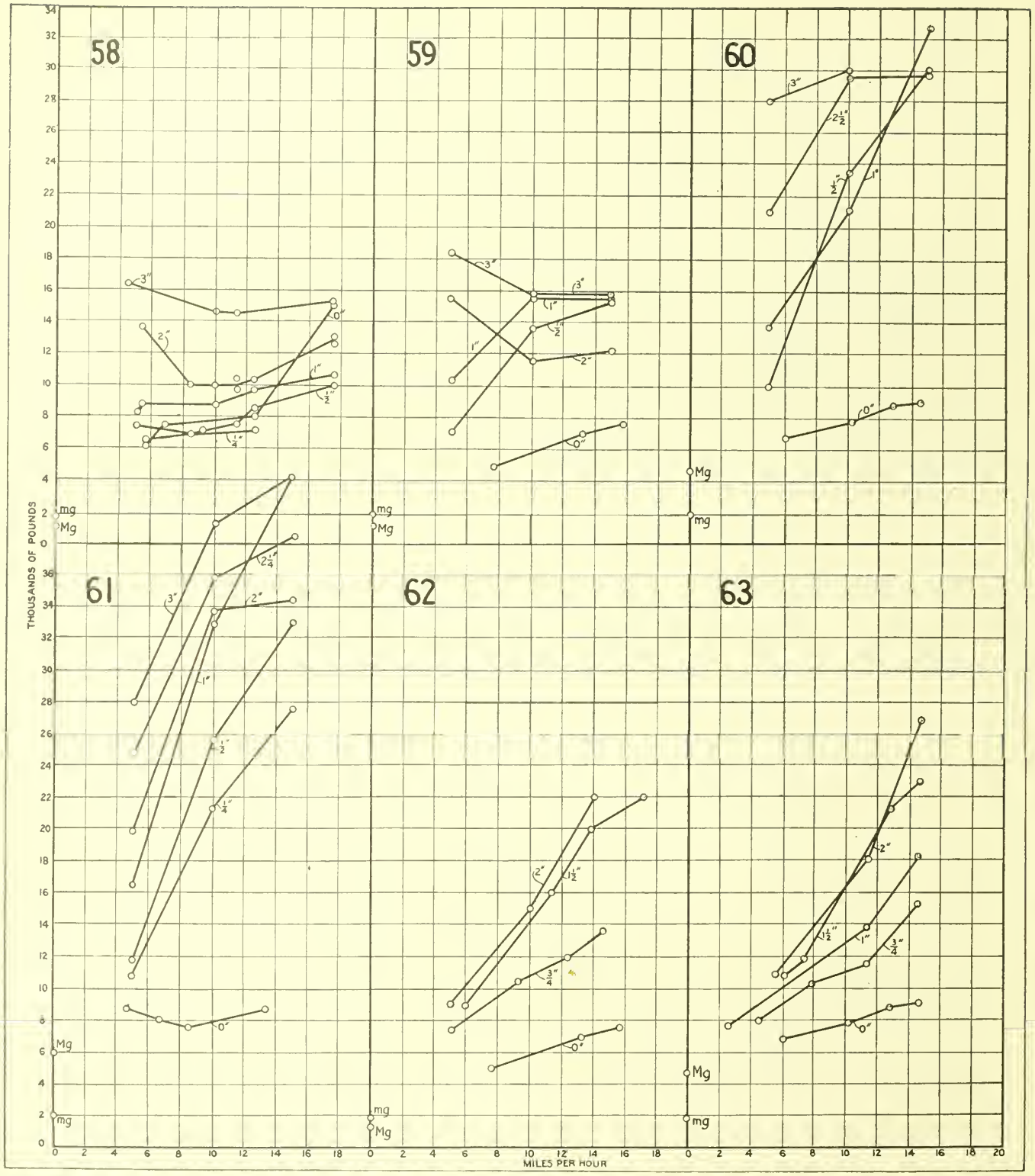


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires.			Springs.		Type of test.
						No.	Kind.	Deformation due to wheel load.	No.	Deflection due to sprung weight.	
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
58	P	3–3½	0	1,150	1,700	18	Solid	0.05	D	0.48	Drop.
59	B	3	0	1,388	1,837		do		A	.74	Do.
60	B	3	3.6	4,700	1,837		do		A	2.62	Do.
61	B	3	5	5,900	1,837		do		A	3.62	Do.
62	B	3	0	1,383	1,837		do		A	.74	Obstruction.
63	B	3	3.6	4,700	1,837		do		A	2.62	Do.

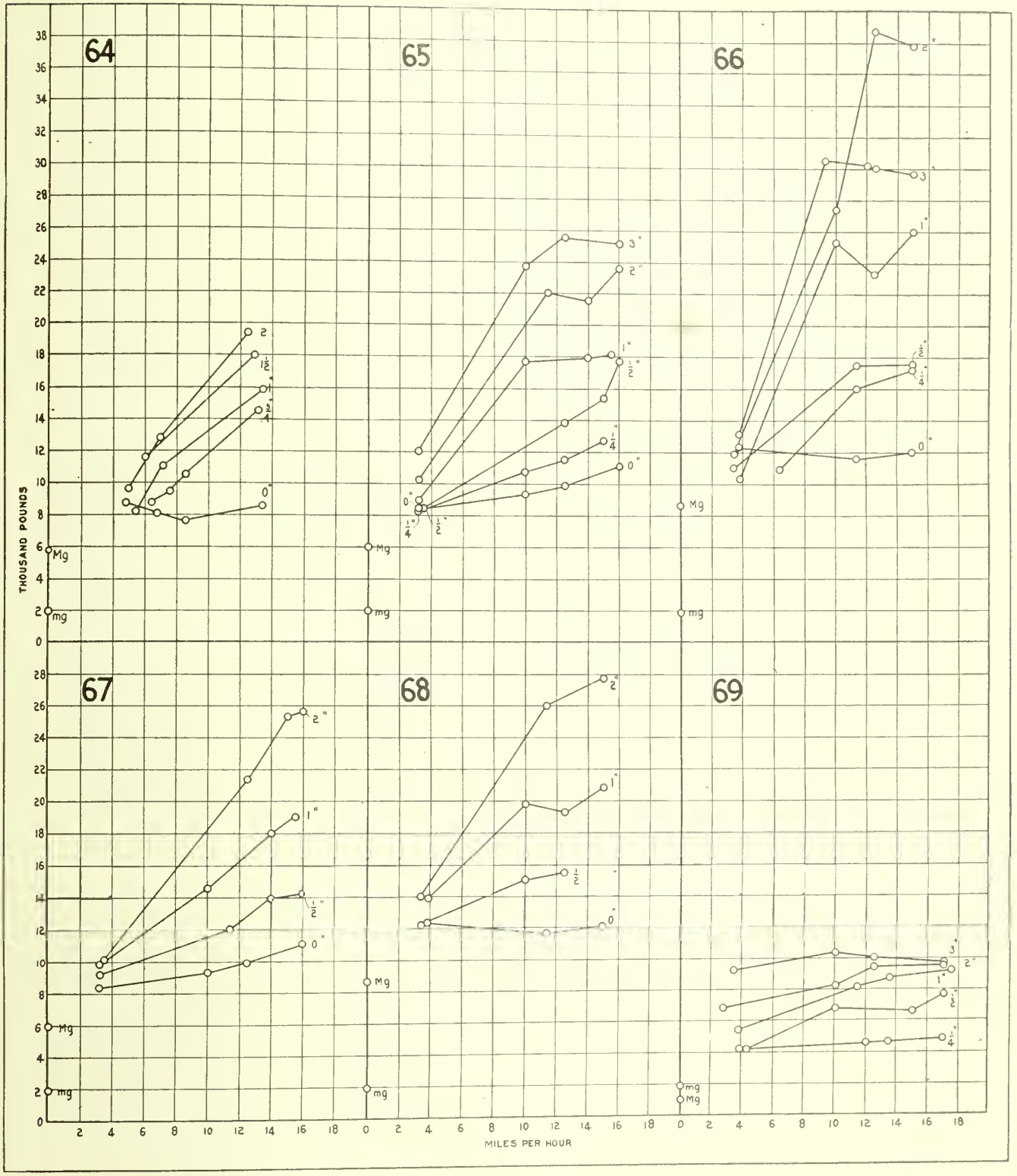


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
64	B	3	5	5,900	1,837	.....	Solid.....	.....	A	3.62	Obstruction.
65	A	5	5	6,950	1,950	13	.....do.....	0.15	F	2.12	Drop.
66	A	5	7½	8,650	1,950	13	.....do.....	.18	F	3.09	Do.
67	A	5	5	5,950	1,950	13	.....do.....	.15	F	2.12	Obstruction.
68	A	5	7½	8,650	1,950	13	.....do.....	.18	F	3.09	Do.
69	A	5	0	1,050	1,950	14	.....do.....	.13	F	.38	Drop.

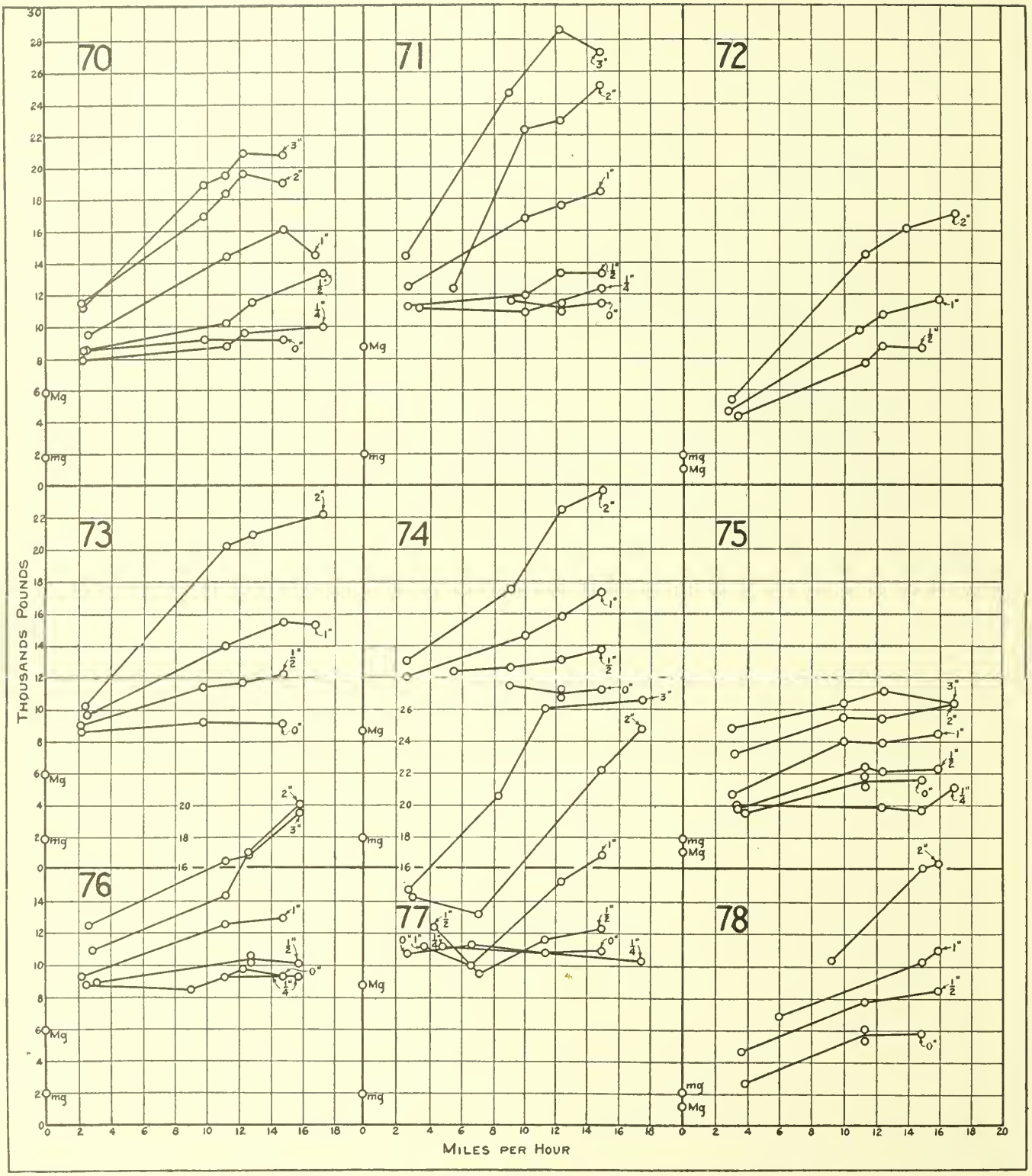


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires.			Springs.		Type of test.
						No.	Kind.	Deformation due to wheel load.	No.	Deflection due to sprung weight.	
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
70	A	5	5	5,950	1,950	14	Solid	0.26	F	2.12	Drop.
71	A	5	7½	8,650	1,950	14	do	.31	F	3.09	Do.
72	A	5	0	1,050	1,950	14	do	.13	F	.38	Obstruction.
73	A	5	5	5,950	1,950	14	do	.26	F	2.12	Do.
74	A	5	7½	8,650	1,950	14	do	.31	F	3.09	Do.
75	A	5	0	1,050	1,950	15	do	.19	F	.38	Drop.
76	A	5	5	5,950	1,950	15	do	.38	F	2.12	Do.
77	A	5	7½	8,650	1,950	15	do	.45	F	3.09	Do.
78	A	5	0	1,050	1,950	15	do	.19	F	.38	Obstruction.

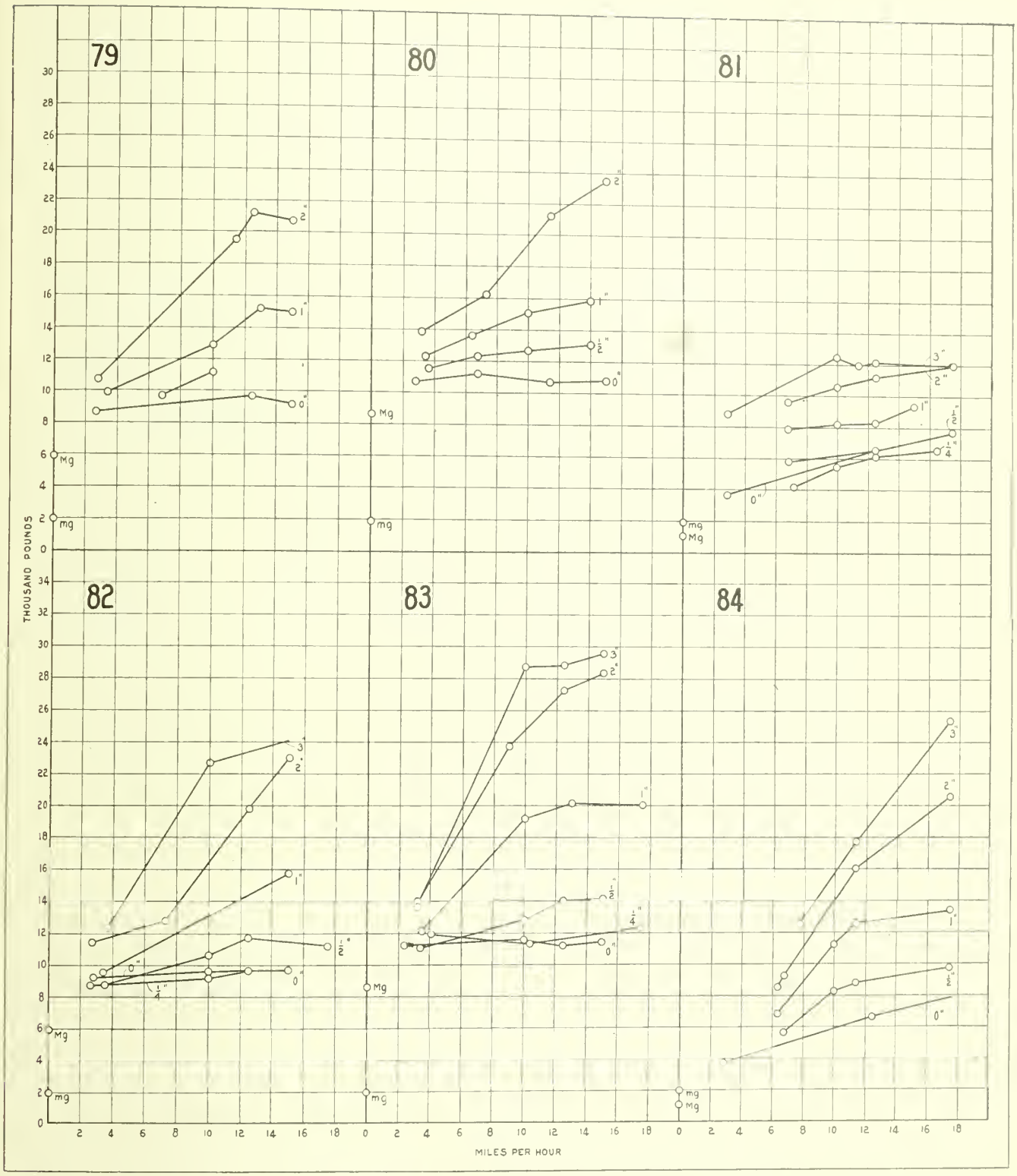


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
79	A	5	5	5,950	1,950	15	Solid	0.38	F	2.12	Obstruction
80	A	5	7½	8,650	1,950	15	do	.45	F	3.09	Do.
81	A	5	0	1,050	1,950	24	do	.18	F	.38	Drop.
82	A	5	5	5,950	1,950	24	do	.36	F	2.12	Do.
83	A	5	7½	8,650	1,950	24	do	.43	F	3.09	Do.
84	A	5	0	1,050	1,950	24	do	.18	F	.38	Obstruction.

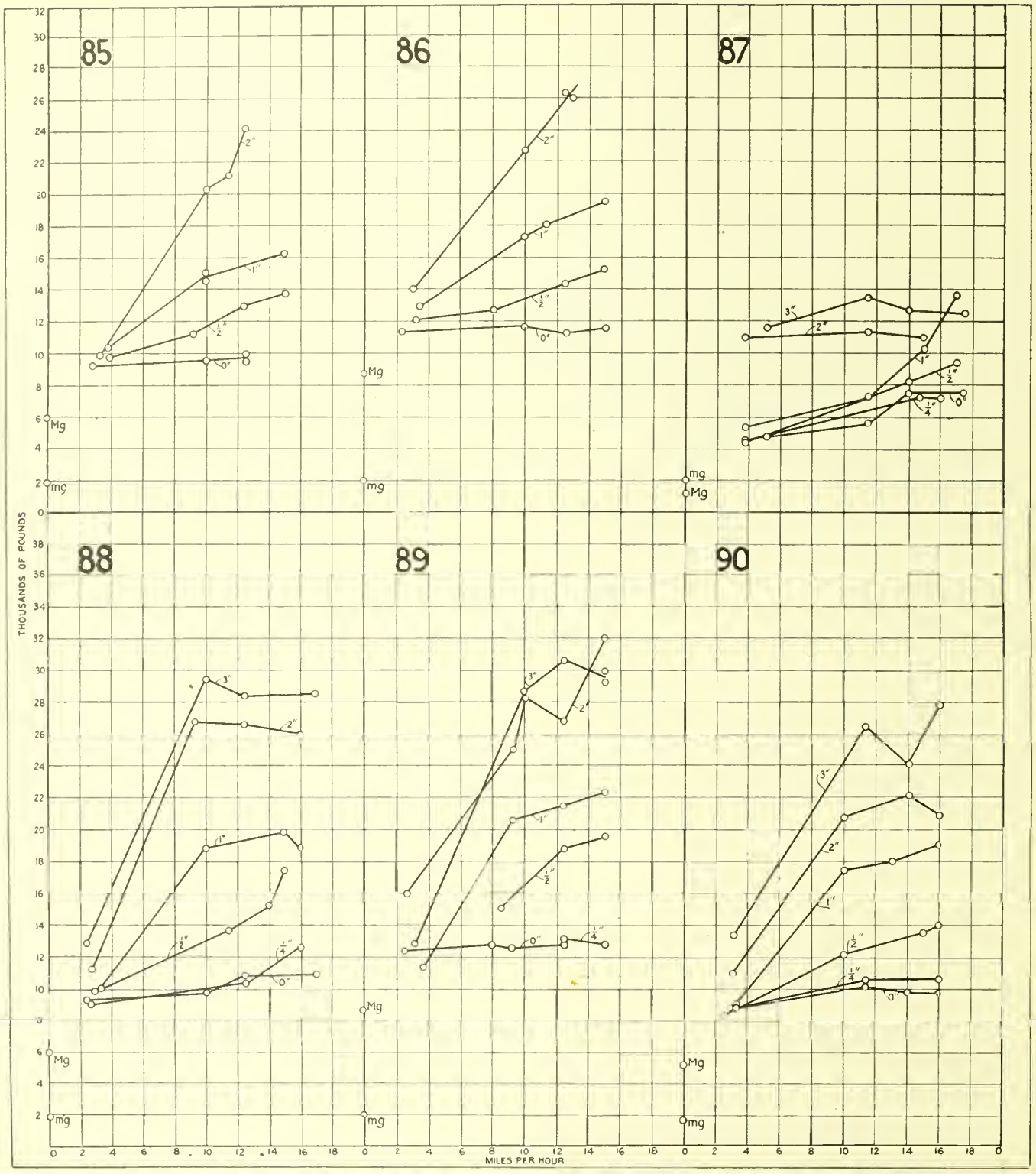


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
85	A	5	5	5,950	1,950	24	Solid	0.36	F	2.12	Obstruction.
86	A	5	7½	8,650	1,950	24	do	.43	F	3.09	Do.
87	A	5	0	1,050	1,950	25	do	.08	F	.38	Drop.
88	A	5	5	5,950	1,950	25	do	.16	F	2.12	Do.
89	A	5	7½	8,650	1,950	25	do	.19	F	3.09	Do.
90	A	5	4.8	5,150	1,950	25	do	.15	F	1.84	Do.

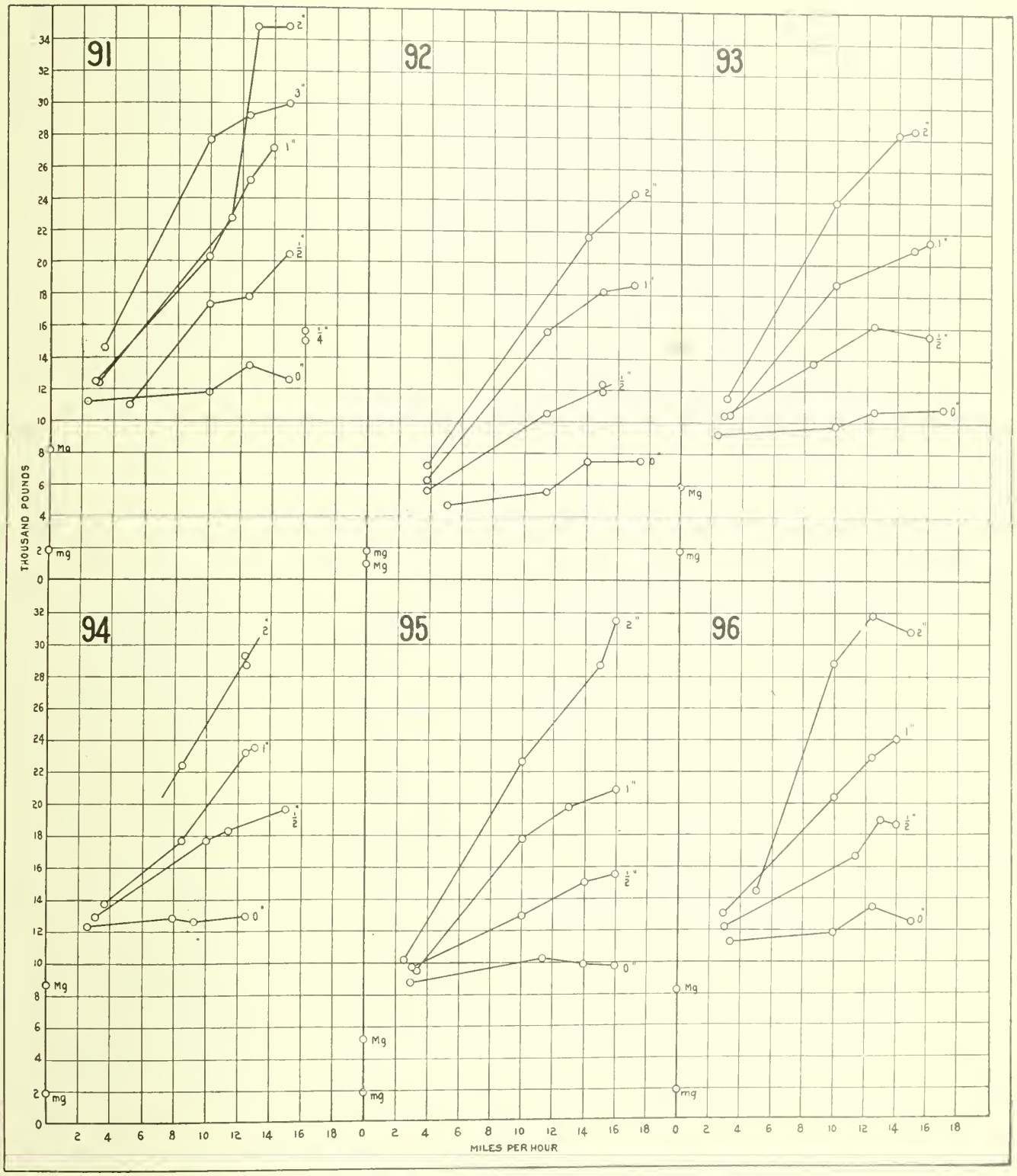


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
91	A	5	6.7	8,150	1,950	25	Solid	0.18	F	2.90	Drop.
92	A	5	0	1,050	1,950	25	do	.08	F	.38	Obstruction.
93	A	5	5	5,950	1,950	25	do	.16	F	2.12	Do.
94	A	5	7½	8,650	1,950	25	do	.19	F	3.09	Do.
95	A	5	4.8	5,150	1,950	25	do	.15	F	1.84	Do.
96	A	5	6.7	8,150	1,950	25	do	.18	F	2.90	Do.

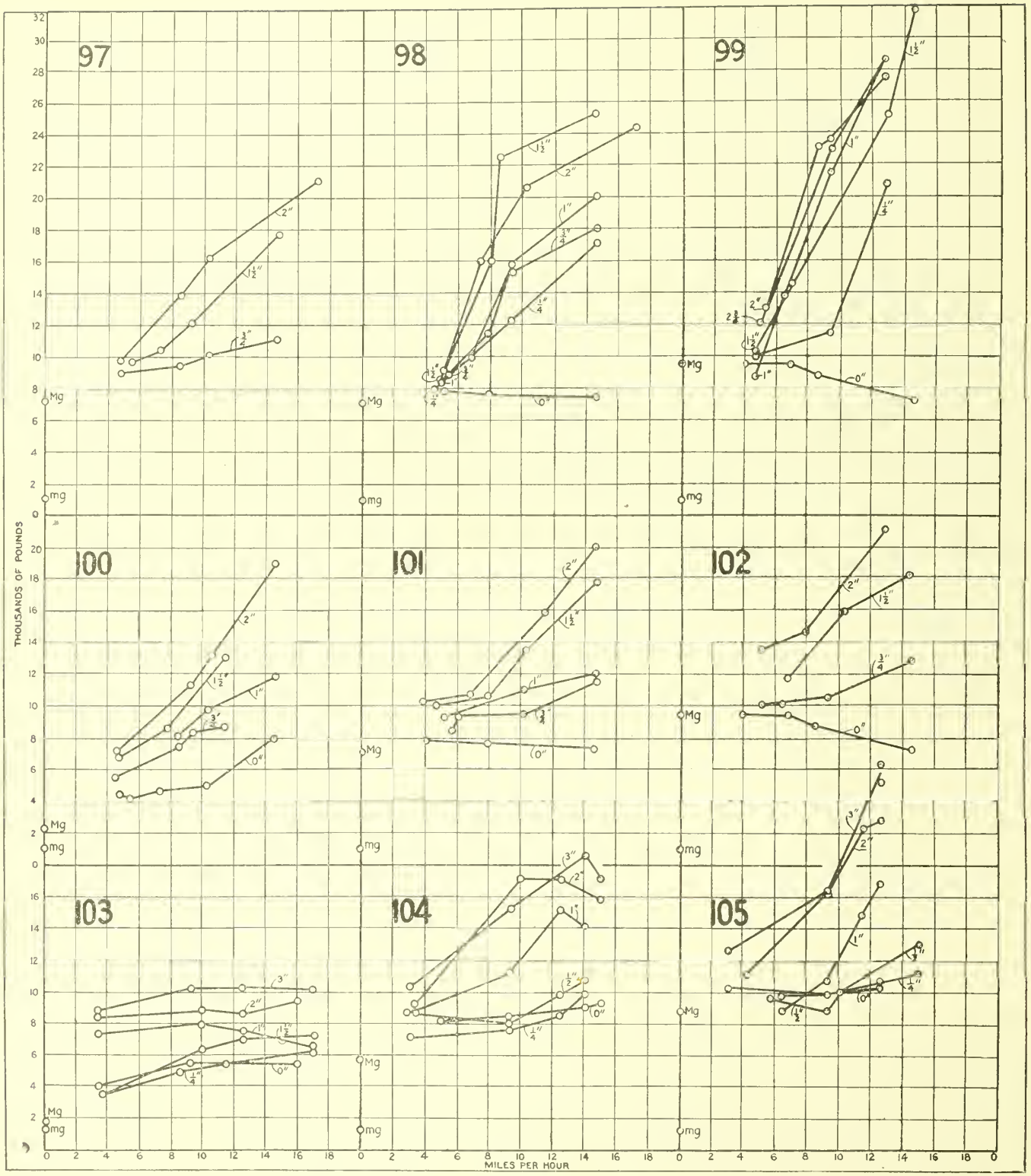


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
97	Ka	5½	5	7,060	1,000	2	Solid	0.23	B	3.73	Iron obstruction.
98	Ka	5½	5	7,060	1,000	2	do	.23	B	3.73	Drop.
99	Ka	5½	7¾	9,575	1,000	2	do	.28	B	5.12	Do.
100	Ka	5½	0	2,250	1,000	2	do	.15	B	1.12	Obstruction.
101	Ka	5½	5	7,060	1,000	2	do	.23	B	3.73	Do.
102	Ka	5½	7¾	9,575	1,000	2	do	.28	B	5.12	Do.
103	Kb	5½	0	1,600	1,300	16	do	.15	G	.53	Drop.
104	Kb	5½	5	5,800	1,300	16	do	.28	G	1.93	Do.
105	Kb	5½	7½	8,800	1,300	16	do	.35	G	2.93	Do.

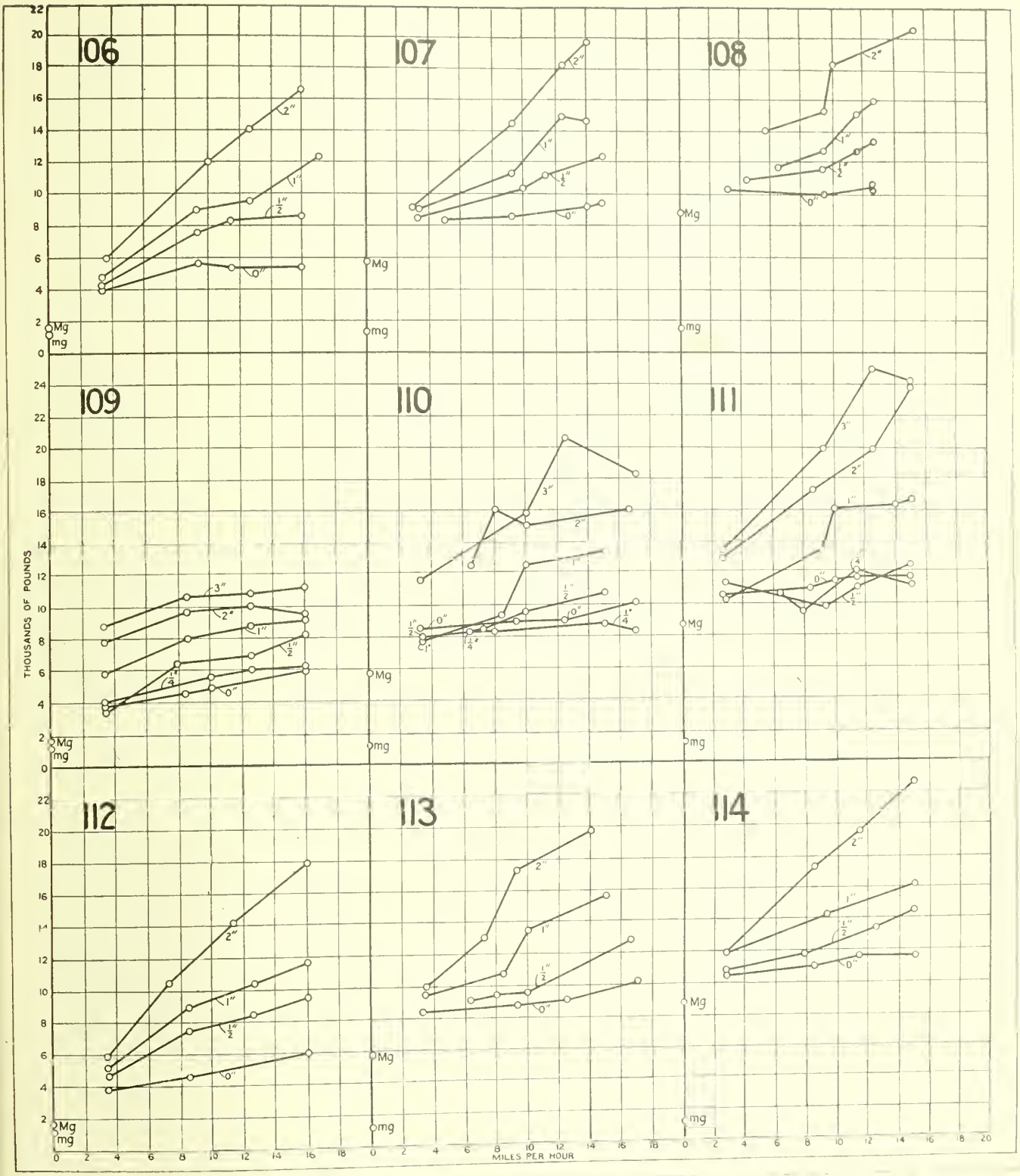


Chart No.	Truck.	Capacity	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Springs. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
106	Kb	5½	0	1,600	1,300	16	Solid	0.15	G	0.53	Obstruction.
107	Kb	5½	5	5,800	1,300	16	do	.28	G	1.93	Do.
108	Kb	5½	7½	8,800	1,300	16	do	.35	G	2.93	Do.
109	Kb	5½	0	1,600	1,300	24	do	.18	G	.53	Drop.
110	Kb	5½	5	5,800	1,300	24	do	.33	G	1.93	Do.
111	Kb	5½	7½	8,800	1,300	24	do	.42	G	2.93	Do.
112	Kb	5½	0	1,600	1,300	24	do	.18	G	.53	Obstruction.
113	Kb	5½	5	5,800	1,300	24	do	.35	G	1.93	Do.
114	Kb	5½	7½	8,800	1,300	24	do	.42	G	2.93	Do.

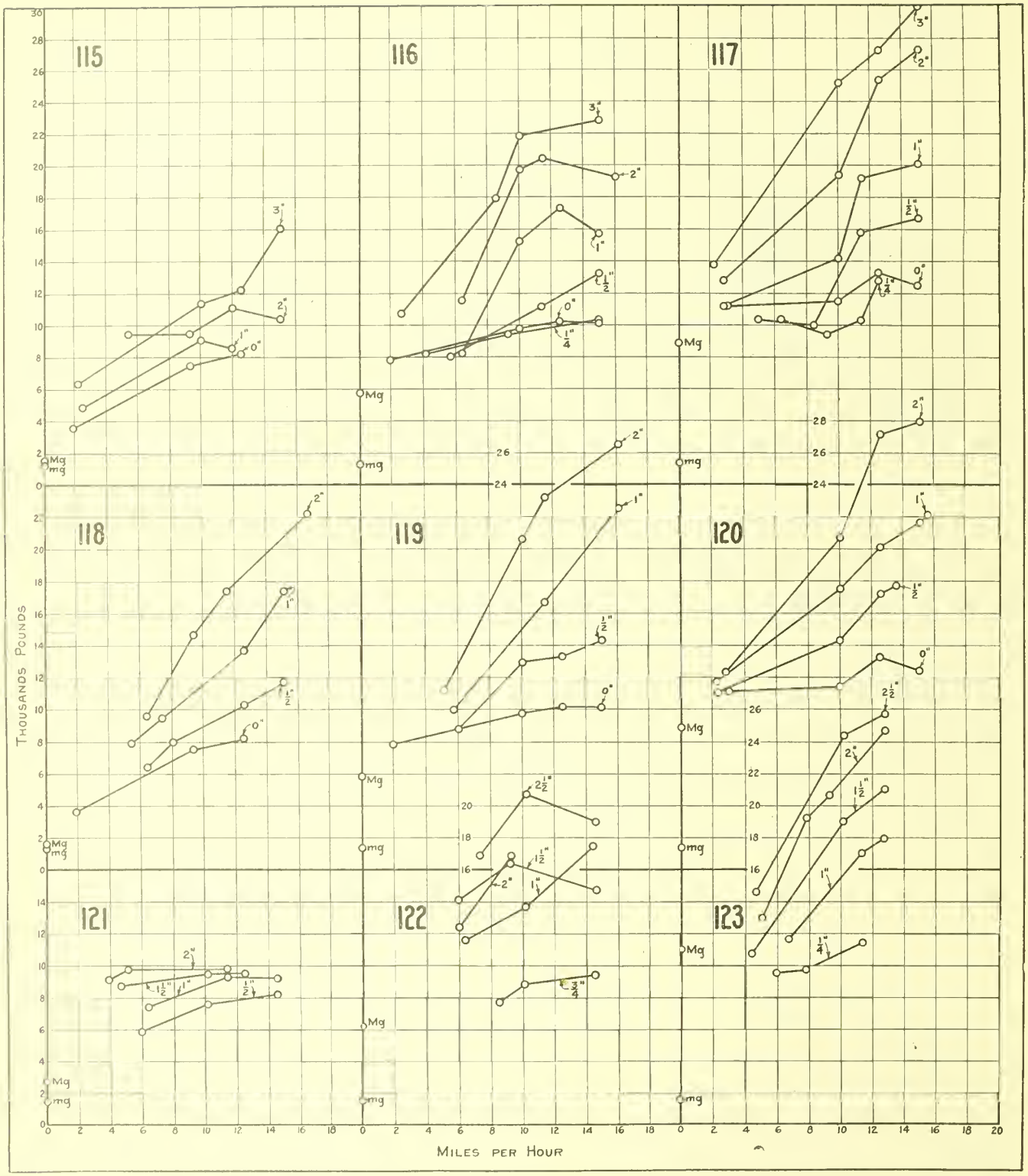


Chart No.	Truck.	Capacity.	Load.	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Tires. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
115	Kb	5½	0	1,600	1,300	25	Solid	0.08	G	0.53	Drop.
116	Kb	5½	5	5,800	1,300	25	do	.15	G	1.93	Do.
117	Kb	5½	7½	8,800	1,300	25	do	.18	G	2.93	Do.
118	Kb	5½	0	1,600	1,300	25	do	.08	G	.53	Obstruction.
119	Kb	5½	5	5,800	1,300	25	do	.15	G	1.93	Do.
120	Kb	5½	7½	8,800	1,300	25	do	.18	G	2.93	Do.
121	Kc	7½	0	2,700	1,500	1	do	.30	C	1.08	Drop.
122	Kc	7½	3*I*	6,200	1,500	1	do	.48	C	2.70	Do.
123	Kc	7½	8½	11,000	1,500	1	do	.60	C	4.78	Do.

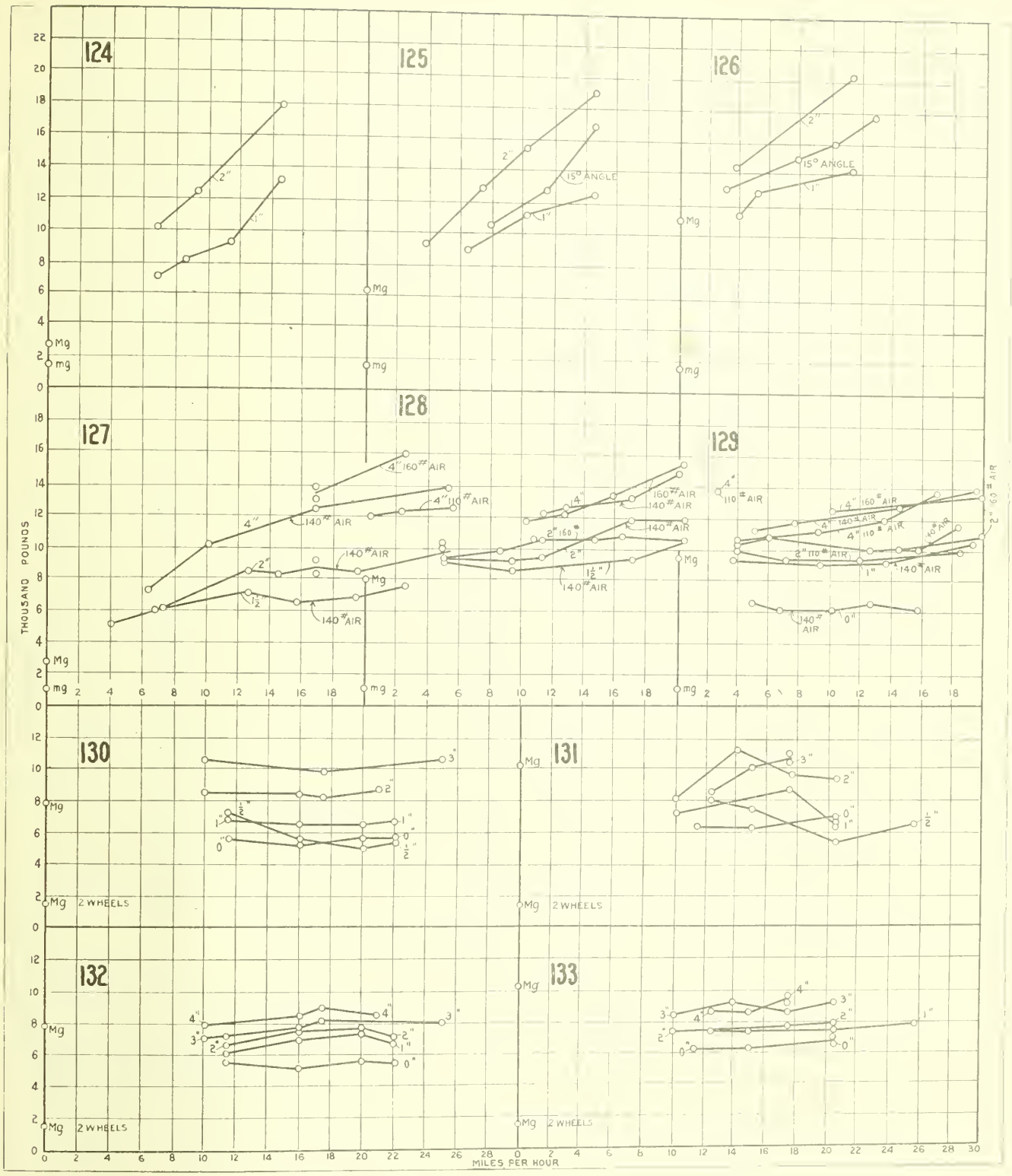


Chart No.	Truck.	Capacity.	Load	Sprung weight on 1 rear wheel (*Mg*).	Unsprung weight on 1 rear wheel (*mg*).	Tires. No.	Tires. Kind.	Springs. Deformation due to wheel load.	Springs. No.	Springs. Deflection due to sprung weight.	Type of test.
		Tons.	*Tons.*	*Pounds.*	*Pounds.*						
124	Kc	7½	0	2,700	1,500	4	Solid	.20	C	1.08	Obstruction.
125	Kc	7½	3.1	6,200	1,500	4	do	.38	C	2.70	Do.
126	Kc	7½	8½	11,000	1,500	4	do	.40	C	1.78	Do.
127	Ks	5	0	2,740	1,130	.....	Pneumatic	.....	.....	.....	Do.
128	Ks	5	6.4	8,080	1,130	.....	do	.....	.....	.....	Do.
129	Ks	5	7.15	9,380	1,130	.....	do	.....	.....	.....	Do.
130	G	5	5	[1] 7,980	[1] 1,500	.....	do	.....	.....	1.65	Drop.
131	G	5	7½	[1] 10,280	[1] 1,500	.....	do	.....	.....	2.62	Do.
132	G	5	5	[1] 7,980	[1] 1,500	.....	do	.....	.....	1.75	Obstruction.
133	G	5	7½	[1] 10,280	[1] 1,500	.....	do	.....	.....	2.62	Do.

this connection it should be stated that the name "cushion" on a tire does not necessarily make it such a tire. Some definitions and deflection requirements should be adopted for the classification of tires. Certainly a tire which does not have at least a deflection value of 40 per cent to 50 per cent of the deflection of a pneumatic tire under the same capacity load should not be classed as a cushion tire.

Pneumatic tires, as might be expected, show a very great influence in reducing impact values, and the impact produced with such equipment seems to increase only very slightly with the speed.

Considering the effect only upon the impact, the width of the tires, or the load per inch of tire width has very little controlling influence. The deflection of the tire is the main factor and this is controlled only slightly by its width. A decrease in tire width increases the load per square inch of tire, which in turn causes a slightly greater tire deflection. This, then, should tend to slightly decrease the impact. It will thus be seen that a large tire width does not tend to decrease the impact, but rather to increase it. It is a fact that a very wide but thin solid tire will give much higher impact forces than a narrow thick one. In so far as the unit load on the road surface is concerned, this must be considered from an entirely different viewpoint.

The speed of the truck has an important influence upon the value of the impact force, but it is a somewhat complex relation. It is not a simple arithmetical ratio, nor can it be expressed simply as a certain power of the speed ratio. When striking an obstruction or irregularity, the curve showing the impact values in relation to speed is approximately a straight line. But the equation of this curve depends upon the characteristics of the truck, the height of the obstruction, and the deflection of the tire, as well as the speed. For approximate comparisons it may be stated that the impact increases with the increase of speed:

10 to 100 per cent for solid tires;
10 to 75 per cent for cushion tires;
and 0 to 10 per cent for pneumatic tires.

An average of any of these limiting percentages must not be used, as the performance of any truck is too variable, and the relation of the other controlling factors can not be predicted.

When dropping from one level to another the speed affects the impact value somewhat according to the percentage variations, given in the preceding paragraph, up to the point of a critical speed of 9 to 12 miles per hour. Beyond the point of critical speed at which the wheel falls freely there should be no increase in impact value.

Although heavy unsprung weights may give higher impact values than lighter unsprung weights, it can not be said that this is the major controlling factor. With all other conditions remaining constant this may be true. But other controlling factors, such as tire equipment, spring stiffness, load carried, and speed, may have a greater influence and overcome any difference due to the unsprung weights.

It is easily possible to so operate a light-weight truck under certain load and speed conditions that it will produce as high impact values as a heavy truck under certain conditions. Much remains to be learned, however, as to the relative destructive effects of light-weight, fast-running vehicles, and slow-moving heavy trucks.

The impact values as shown on the accompanying charts may be as high as 7 times the load at one rear wheel for a solid tire over a 1-inch obstruction at 16 miles per hour; an average value being about 4 times. For pneumatic tires the maximum impact value is probably not more than one and three-fourths times the load at one rear wheel, and an average value is not more than 25 per cent.

REPORT ON CALIFORNIA HIGHWAYS READY.

The report of the Bureau of Public Roads on the study of the California highway system made by the bureau has been completed and will be published by the California Commission about March 30.

The report, which was transmitted to the State Commission by Secretary of Agriculture, E. T. Meredith on February 18, covers the work done at the request of the California Highway Commission and Highway Engineer since July 8, 1920. The field studies and the preparation of the report were carried forward under the immediate direction of Dr. L. I. Hewes and T. Warren Allen, general inspectors of the Bureau of Public Roads.

The published report will contain about 58,000 words and numerous tables, together with 11 appendices. It is profusely illustrated with photographs and 115 maps and diagrams. Bound in cloth it will make a valuable addition to highway engineering libraries.

It is the most comprehensive study [illegible] obtained through the development of a State highway system that has yet been u[illegible] work follows two principal lines; one that [illegible] those questions that are engineering [illegible] and the other those that are economic in[illegible]

For the purpose of the study, the p[illegible] tion was to classify all the paveme[illegible] classification covered 1,262 miles fr[illegible] complete record of all concrete pave[illegible] one-tenth mile resulted, and is suppo[illegible] consecutive photographs filed in the bur[illegible]

An abstract of the report will be pu[illegible] April issue of Public Roads.

Acknowledgment is made to Mr. J. T. Pauls for his painstaking and thorough effort in conducting the field tests, and for his aid in preparing and plotting the charts; and to Mr. C. A. Hogentogler for helping to secure and analyze the data. This investigation is done under the general direction of Mr. Thos. H. MacDonald, Chief of the Bureau of Public Roads, and Mr. A. T. Goldbeck, Engineer of Tests.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN JANUARY, 1921.

State.	Project No.	County.	Length.	Type of construction.	Project statements approved.	Estimated cost.	Federal aid.
			Miles.				
Arizona	25	Prima and Santa Cruz		Bridges	Jan. 15	$52,000.74	$26,000.37
	27	Santa Cruz	14.500	Gravel	...do	114,603.50	57,301.75
	41	Maricopa	[1] 6.473	Concrete	Jan. 7	[1] 200,000.24	100,000.12
Arkansas	32	Hempstead	[3] 3.940	Gravel	Jan. 18	[3] 29,647.04	[1] 19,000.00
	39	Grant	[1] 14.300	.....do	Jan. 25	[1] 52,090.50	[1] 15,000.00
	74	Searcy		Bridge	Jan. 27	[1] 34,650.00	[1] 15,600.00
	110	Chicot	[1] 2.000	Concrete	Jan. 26	[1] 37,041.98	[1] 4,200.00
Colorado	30	Jefferson	.977	.....do	Jan. 6	68,999.99	19,540.00
	51	Cheyenne	[3] 4.334	Gravel	Jan. 21	[3] 27,865.54	[3] 13,932.77
	54	Chaffee	5.099	Earth	Jan. 28	110,775.50	55,387.75
	85	Larimer	1.295	Concrete	Jan. 6	57,963.95	25,900.00
	88	Boulder	1.316	.....do	Jan. 21	57,975.70	26,320.00
	89	Adams	4.413	.....do	Jan. 6	175,983.50	87,991.75
	122	Sedgwick	8.500	Gravel	Jan. 22	68,202.75	34,101.37
	125	Gunnison	2.819	Earth and gravel	Jan. 26	88,810.26	44,405.13
	126	Montezuma	2.992	Gravel	Jan. 21	39,314.55	19,657.27
Connecticut	7	New London	4.250	Bituminous macadam	Jan. 6	189,456.30	85,000.00
Georgia	13	Muscogee		Bridge	Aug. 2	[1] 59,950.00	[1] 29,975.00
	27	Polk	[1] 14.700	Top soil	...do	[1] 41,184.00	[1] 20,000.00
	37	Dekalb	[1] 5.500	Concrete	...do	[1] 134,778.38	[1] 45,591.04
	72	Gwinnett	[1] 10.000	.....do	...do	[1] 51,154.71	[1] 25,577.35
	188	Randolph	[3] 6.500	Sand-clay	Jan. 15	[3] 45,884.08	[3] 7,500.00
	189	Hart	4.000	.....do	Jan. 4	26,793.80	13,396.90
	195	Glynn and McIntosh	4.830	Shell	Jan. 6	195,647.58	90,000.00
	194	Fayette	2.270	Topsoil	Jan. 26	15,102.82	7,551.41
	209	Tift		Bridges	...do	36,300.00	18,150.00
	217	Barton	2.000	Gravel	Jan. 17	22,000.00	11,000.00
	213	Worth	4.340	Earth and hard surface	Jan. 26	176,180.53	25,000.00
	216	Columbia	4.000	Sand-clay	...do	28,585.37	14,000.00
Indiana	16	Vanderburg, Warrick, Spencer, Dubois, Orange, Lawrence.		Earth, brick, concrete, or bituminous concrete.	Jan. 21	[2]2,115,596.26	[2]1,057,798.13
	27	Noble	14.500	Brick, concrete, or bituminous	Jan. 15	636,900.00	318,450.00
Kansas	50	Bourbon, Crawford	[1] .521	Bituminous macadam	Jan. 14	16,182.52	7,815.00
	73	Cherokee	13.340	Gravel	Jan. 28	378,840.00	103,800.00
Louisiana	51	St. Charles	[1] 6.230	Sand-clay, gravel	...do	[1] 62,531.15	[1] 31,265.57
	57	Grant and La Salle		Bridges	Jan. 24	[1] 16,991.15	[1] 8,495.57
	83	Caldwell	14.900	Gravel	...do	195,749.84	88,000.00
Maryland	48	Harford	3.040	Concrete	Jan. 22	120,973.60	60,486.80
Massachusetts	45	Hampden	2.325	Bituminous macadam	Jan. 4	79,761.00	39,880.50
	49	Plymouth	2.108	.....do	Jan. 22	50,923.40	25,461.70
	50	Worcester	1.763	Bituminous concrete	...do	71,520.46	35,260.00
	51	.....do	4.498	Bituminous macadam	Jan. 24	276,511.73	89,960.00
	52	.....do	3.208	Concrete	Jan. 21	178,774.75	64,160.00
	53	.....do	3.068	Bituminous macadam	Jan. 28	153,741.50	61,360.00
	54	.....do	3.591	.....do	Jan. 24	197,692.00	71,820.00
Michigan	57	Kent	17.320	Concrete or bituminous concrete	Jan. 28	778,442.50	346,400.00
Minnesota	118	Carver	[3] 12.480	Gravel	Jan. 7	[3] 45,005.62	[3] 3,699.02
Mississippi	19	Montgomery	[1] 9.110	.....do	Jan. 27	[1] 30,573.84	[1] 15,000.00
	29	Union	[2] 12.670	Gravel or slag	Jan. 28	[2] 87,403.25	[2] 15,796.63
	49	Coahoma	[1] 10.680	Concrete	Jan. 12	[1] 320,485.44	[1] 100,000.00
	103	Leake	14.100	Earth	Jan. 28	99,772.75	49,886.37
	111	Madison	14.000	.....do	...do	58,300.00	29,150.00
Montana	150	Sanders		Bridge	Jan. 26	96,992.50	48,496.25
New Mexico	61	Bernalillo	[3] .400	Concrete	...do	[3] 19,151.00	[3] 9,575.50
	63	Curry	12.000	Caliche	Jan. 22	92,803.70	46,401.85
	65	Rio Arriba		Bridge	Jan. 28	48,836.15	24,418.07
North Dakota	115	Adams	3.000	Earth	Jan. 14	13,860.00	6,930.00
Ohio	70	Allen	[1] 4.430	Bituminous macadam	Jan. 7	[1] 123,000.00	[1] 43,600.00
	124	Auglaize	[1] 5.306	Concrete	...do	[1] 220,000.00	[1] 72,000.00
Oklahoma	49	Pittsburg		Bridge	Jan. 15	40,000.00	20,000.00
	50	Benton	7.960	Concrete	Jan. 22	247,929.00	123,964.50
	60	Beaufort		Bridge	Jan. 27	[1] 207,900.00	[1] 103,950.00
Texas	58	Navarro	[1] 11.540	Macadam	Jan. 31	[1] 133,102.20	[1] 66,551.10
	230	Denton	5.430	Gravel	Jan. 17	58,791.81	25,000.00
	232	Comanche	8.000	.....do	Jan. 6	126,297.69	31,574.42
	10	Uintah	22.620	.....do	Jan. 12	413,002.04	206,501.02
West Virginia	110	Wyoming	4.000	Earth	Jan. 22	94,076.00	47,038.00

...celled.
...t. Amounts given are decreases from those in original statement.
...ent. Amounts given are increases over those in the original statement.

PROJECT AGREEMENTS EXECUTED IN JANUARY, 1921.

	Project No.	County.	Length.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
			Miles.				
	6A	Apache	3.000	Gravel	Jan. 21	$30,607.83	$15,303.91
	15D	Graham	5.026	.....do	...do	64,088.55	32,044.27
	31	Maricopa		Bridge	Jan. 18	78,895.85	39,447.92
	38	Cochise	26.370	Gravel	Jan. 21	160,603.52	80,301.76
	39	Mohave	23.000	Gravel and earth	Jan. 18	177,430.35	88,715.17
Arkansas	55	Prairie	3.830	Gravel, surface treated	Jan. 31	55,277.78	21,400.00
	63	White	11.010	.....do	Jan. 26	96,854.72	36,300.00
Colorado	59	Bent		Gravel	Jan. 5	[3] 31,153.52	[3] 15,576.76
	123	Eagle and Garfield		Earth	Jan. 7	[3] 51,509.37	[3] 25,754.69
Delaware	2	Sussex		Concrete	Jan. 24		[4] 162,674.82

Footnotes on page 39.

PROJECT AGREEMENTS EXECUTED IN JANUARY, 1921—Continued.

State.	Project No.	County.	Length.	Type of construction.	Project agreements signed.	Estimated cost.	Federal aid.
			Miles.				
Georgia	9	Brooks		Bituminous macadam	Jan. 26	[4] $137,468.70	[4] $34,320.00
	76	Wheeler		Sand-clay	Jan. 21	[3] 21,005.23	[3] 9,088.31
	117	Gwinnett	[3] 0.193	Topsoil	...do	[3] 90,929.48	[3] 51,005.42
	144	Macon		Sand-clay	...do	[3] 1,424.01	[3] 712.00
	151A	Wayne	3.250	Topsoil	...do	16,254.46	8,127.23
	162	Gwinnett	6.120	...do	...do	79,216.35	39,608.17
	164	Macon		Bridge	...do	28,975.30	12,513.08
	178	Murray	6.670	Topsoil	...do	78,822.84	39,411.42
	181	Dekalb	1.913	Bituminous macadam	...do	69,122.91	5,000.00
	199	Quitman	5.000	Sand-clay	...do	30,454.21	15,227.10
	202	Wilcox	1.130	Gravel	...do	21,764.60	10,882.30
Illinois	1-23	Lee	0.807	Concrete	Jan. 4	27,928.49	13,964.24
	1-M	Kane	0.487	Concrete and brick	...do	22,752.95	9,740.00
	2-M	Iroquois	0.698	Concrete	...do	27,006.52	13,503.26
	9-W	Fayette	1.894	Earth and four bridges	Jan. 27	210,241.28	52,560.32
	11-S	Vermilion		Bridge	Jan. 4	27,858.61	13,929.30
	14-9, 10, 11	Jackson and Union	13.299	Earth	Jan. 17	247,202.80	61,800.69
	15-5	Williamson	3.763	...do	Jan. 27	122,556.18	30,639.04
	17-1, 2	Adams	14.392	...do	Jan. 4	213,378.29	53,344.57
Indiana	16-EF	Spencer and Dubois	16.996	Earth and brick, concrete or bituminous concrete.	Jan. 19	237,258.06	118,629.02
Iowa	83ABCD	Union	14.503	Earth	Jan. 27	111,494.84	16,900.00
	91BCD	Wayne	10.950	...do	...do	79,604.41	39,000.00
	122	Decatur	9.929	...do	...do	76,051.91	31,800.00
Kansas	44	Saline		...do	Jan. 6	[2] 278,627.27	[2] 63,000.00
	45	...do		...do	...do	[2] 393,639.05	[2] 84,180.00
	50	Bourbon	[1] .520	Bituminous macadam	Jan. 14	[1] 16,208.58	[1] 7,800.00
	52	Wyandotte and Leavenworth	7.968	Concrete	Jan. 31	494,033.15	119,520.00
	62	Morris	6.809	Bituminous macadam	Jan. 25	341,773.43	97,000.00
	65	Allen	2.003	Concrete	Jan. 25	96,248.24	30,045.00
	69	Saline and Ottawa	1.989	Earth	Jan. 16	22,476.85	5,967.00
	71	Cherokee	3.073	Concrete	Jan. 24	283,220.74	46,095.00
Louisiana	65	St. Martin	4.950	Gravel	Jan. 14	76,972.41	38,486.22
Maryland	7-D	Baltimore	.146	Waterbound macadam	Jan. 12	9,565.71	2,920.00
	40	...do	2.410	Sheet asphalt	Jan. 5	98,445.38	48,200.00
	42	Anne Arundel	2.120	Concrete	...do	82,508.80	41,254.40
	43	Prince Georges	0.504	Sheet asphalt	...do	21,298.75	10,000.00
Michigan	1AB	Oceana and Muskegon	9.942	Concrete	Jan. 26	379,933.79	189,966.89
	26	Antrim	7.839	Gravel	Jan. 15	119,167.33	59,583.66
	33CD	Alcona	7.837	...do	Jan. 21	128,607.21	64,303.60
Minnesota	1	Pine		...do	Jan. 19	[5] 52,490.14	[5] 26,245.07
	17	Carlton		...do	Jan. 7	[5] 3,851.95	[5] 1,925.97
	22	Dakota	17.035	Earth	Jan. 12	217,115.81	108,557.90
	31	Kandiyohi		Concrete	Jan. 24	[4] 19,185.40	[4] 23,425.14
	40AB	Meeker		Gravel	Jan. 25	[3] 8,560.12	[3] 6,288.88
	45	Nobles	18.960	...do	Jan. 5	155,346.95	65,000.00
	74	Sibley	9.700	...do	Jan. 25	73,871.16	36,935.58
	114	Sherburne	[3] 1.297	Concrete	...do	[3] 48,462.52	[3] 24,231.22
	140	Cass	12.430	Gravel	Jan. 10	95,634.15	25,000.00
	153A	Blue Earth	6.914	...do	Jan. 5	92,771.74	46,000.00
	162	Beltrami	12.120	...do	Jan. 12	76,072.31	15,000.00
	176	Itasca		...do	Jan. 24	[3] 3,583.25	[3] 14,656.24
	188	Freeborn	4.965	...do	Jan. 20	44,992.87	3,000.00
	195	Lac qui Parle	8.010	...do	Jan. 5	21,019.50	10,000.00
Mississippi	30	Lauderdale	[1] 1.000	...do	Jan. 20	[4] 7,272.16	[4] 3,636.08
	42	Pike	9.739	...do	Jan. 29	100,052.46	50,031.23
	49	Coahoma	[1] 10.660	Concrete	Jan. 12	[1] 319,877.77	[1] 100,000.00
Missouri	62	Macon		Gravel	Dec. 21	[3] 41,385.34	[3] 20,693.17
	84	Jasper	6.470	Concrete	...do	231,072.51	115,536.25
	121A	Barry	4.880	Gravel	...do	60,341.33	30,170.66
	122	Pettis		Bituminous macadam	...do	[3] 8,853.46	[3] 4,426.73
	150AB	Greene	31.330	Gravel	...do	243,676.35	121,838.17
Montana	9A	Madison		...do	Jan. 4	[4] 41,793.58	[4] 20,896.79
	15	Rosebud	[3] 0.784	...do	Jan. 20	[3] 27,220.22	[3] 13,610.11
	94	Meagher		Earth	Jan. 4	[3] 28,164.33	[3] 14,082.17
	108A	Musselshell	11.323	...do	...do	74,834.73	37,417.36
	136	Teton	13.240	Gravel	Jan. 3	84,428.64	42,214.32
Nevada	34	Churchill	8.290	Gravel	Dec. 28	121,148.80	60,574.40
New Mexico	13A	Valencia		Gravel and sand-clay	Jan. 17	[4] 3,495.14	[4] 1,747.57
	44	Hidalgo	8.000	Gravel	Jan. 22	48,959.70	24,479.85
New York	22	Broome		Bituminous macadam	Jan. 27	[3] 7,500.00	[3] 2,625.00
	69	Delaware		Reinforced concrete	Jan. 10	[3] 75,300.00	[3] 26,355.00
North Carolina	26	Davidson	[2] 4.462	Topsoil	Jan. 31	[2] 7,906.63	[2] 2,524.98
	33	Montgomery	[2] 7.064	...do	...do	[2] 6,975.69	
	55B	Mecklenburg	4.590	Bituminous macadam	...do	188,445.18	91,800.00
	59	Columbus		Sand-clay	Jan. 22	[3] 18,407.62	[3] 9,203.81
	66	Haywood	6.177	Topsoil	Jan. 4	85,413.95	42,706.97
	70A	Jackson	4.832	Gravel	Jan. 7	136,743.31	68,371.65
	91	Surry		Topsoil	Jan. 22	[4] 13,581.37	[4] 6,790.69
	96	Yancey	2.946	Gravel	...do	82,653.12	41,326.56
	99	Chatham		Topsoil	...do	[3] 32,448.15	[3] 16,224.07
	100AB	Avery	14.001	Waterbound macadam	...do	267,013.28	133,506.63
	125A	Alleghany	4.985	...do	...do	153,899.13	76,949.56
Ohio	89	Madison	2.421	Bituminous macadam	Jan. 24	81,200.00	25,000.00
	96	Paulding		Bituminous macadam, Kentucky rock asphalt.	Jan. 4	[3] 29,200.00	[3] 20,400.00
	154	Clermont	3.548	Water-bound macadam	Jan. 15	104,600.00	39,320.00
	175	Hocking	5.351	Bituminous macadam	...do	220,000.00	82,000.00
Oklahoma	18	Muskogee		Gravel	Jan. 26	[3] 170,495.17	[3] 85,248.08
Oregon	4	Wheeler		...do	Jan. 4	[3] 78,207.80	[3] 39,103.90
	12	Yamhill		Waterbound macadam	...do		[3] 5,000.00
	17	Malheur		Earth	...do	[3] 4,089.25	[3] 2,044.62
	24	Gilliam		Gravel	...do	[3] 151,151.00	[3] 75,575.50
	25	Sherman		...do	...do	[3] 129,051.45	[3] 64,525.73
	35	Wasco		...do	...do	[3] 45,760.00	[3] 22,880.00
	44	Gilliam	9.210	...do	...do	51,040.00	25,520.00
Pennsylvania	85	Dauphin and Perry	7.908	Reinforced concrete	Jan. 21	507,518.80	158,160.00
	91	Lancaster	5.412	...do	Jan. 28	339,171.92	108,240.00
	92	Delaware	2.838	Concrete	...do	170,167.08	56,760.00
	94	Northumberland	3.053	Reinforced concrete	...do	139,790.97	61,060.00
	95	Lycoming	5.570	...do	...do	441,291.75	111,400.00
Rhode Island	11	Providence	5.000	Bituminous concrete	Jan. 19	248,660.28	100,000.00

Footnotes on page 39.

PROJECT AGREEMENTS EXECUTED IN JANUARY, 1921—Continued.

State.	Project No.	County.	Length.	Type of construction.	Project agreements signed.	Estimated cost.	Federal aid.
			Miles.				
South Carolina	13	Chester and Union		Bridge	Jan. 15	$80,254.78	$[illegible]
	28	Orangeburg		Concrete and sand-clay	Jan. 19	[2] 4,749.35	
	44	Clarendon	7.830	Sand-clay	Jan. 11	79,843.61	[illegible]
	96	Anderson	8.414	Topsoil	Jan. 21	112,801.52	[illegible]
Texas	42	Tarrant	[3] 3.327	Gravel, bituminous top	Jan. 28	[3] 118,941.15	[3] 59,470.57
	61	Wichita		Concrete	Jan. 10	[4] 29,973.41	[4] 50,000.00
	73	Guadalupe		Rock asphalt	Jan. 15	[4] 44,097.16	[4] 22,048.58
	88B	Cass	10.990	Gravel	Jan. 26	126,741.98	35,000.00
	128C	Montague	3.920	Gravel and sand-clay	Jan. 12	49,964.98	22,500.00
	142	Harrison		Gravel, surface treatment	Jan. 25		[3] 15,532.19
	158	Hemphill	13.440	Sand-clay	Jan. 10	82,717.61	40,000.00
	166	Atacosa	13.500	Gravel, bituminous top	Jan. 15	301,356.09	142,866.61
	176	Runnels	5.760	Gravel	Jan. 25	40,248.54	20,124.27
Utah	19C	Pinte		Bridge	Jan. 17	19,181.49	9,590.74
Vermont	17	Windsor		Bridge	Jan. 19	17,095.65	8,547.82
	20	Washington		do	Jan. 22	33,765.98	16,882.99
Virginia	91	King George	9.250	Gravel	Jan. 31	80,878.20	40,439.10
	106	Southampton	0.980	Concrete	Dec. 28	64,034.50	19,600.00
Washington	41	Thurston		Gravel	Jan. 3	[3] 24,879.80	[3] 12,001.97
	44	Clarke		Concrete	Dec. 20		[4] 8,500.00
	78	Skamania	1.240	Gravel	Jan. 3	42,014.83	21,000.00
	79	Lincoln	2.010	Earth	Jan. 25	48,163.28	24,000.00
	80	Benton	1.613	Gravel	Jan. 3	24,709.61	12,000.00
Wisconsin	12	Dane		Waterbound macadam	Jan. 11	[3] 18,437.23	[3] 11,691.39
	13	Clark		Gravel	Jan. 17		[3] 3,380.52
	22	Jefferson and Dodge		do	Jan. 13		[3] 6,000.00
	45	Ashland		Earth	do	[3] 1,656.55	[3] 1,552.18
	82	Vernon		Bituminous macadam	Jan. 7	[3] 35,073.65	[3] 19,361.42
	105	Monroe	3.760	Shale	Jan. 26	38,088.34	10,481.31
	125	Taylor	4.500	Gravel	Jan. 18	48,551.05	21,116.17
	126	St. Croix	2.730	Concrete	Jan. 4	99,701.23	10,542.91
	134	Juneau	5.280	Topsoil	Jan. 18	44,608.63	16,193.52
	137	Lafayette	1.540	Earth and concrete	Jan. 13	42,962.00	16,481.00
	139	Brown		Concrete	Jan. 11		[3] 1,474.07
	140	Iowa	8.180	Earth	do	121,520.09	50,000.00
	165	Vilas	9.510	do	Jan. 26	67,392.75	25,000.00
	176	Sauk	1.310	Gravel	Jan. 7	21,876.25	8,938.12
	177	do	3.620	do	do	52,442.69	21,000.00
Wyoming	19	Natrona		Concrete	Jan. 25	[3] 120,981.47	[4] 48,541.27

[1] Canceled.
[2] Modified agreement. Amounts given are decreases from those in the original agreements.
[3] Modified agreement. Amounts given are increases over those in the original agreements.
[4] Modified agreement. Amounts given are increases. Second revision.
[5] Modified agreement. Amounts given are increases. Third revision.

CONSTRUCTION AND MAINTENANCE IN ILLINOIS.

A total of 341 miles of durable hard surfaced roads was built by the State of Illinois during 1920. According to the State highway department this is a greater mileage of high type construction than has been built in any previous year by any State, and more than any other State built during 1920 except Pennsylvania which completed 410 miles.

The mileage completed during 1920 is distributed as follows:

	Miles.
Lincoln Highway	51
Dixie Highway	46
National Old Trails Road	69
Chicago-East St. Louis Road	113
Chicago-Waukegan Road	9
State-aid Work	53
	341

There are still uncompleted contracts on the above roads approximately as follows:

	Miles.
Lincoln Highway	12
Dixie Highway	20
National Old Trails Road	48
Chicago-East St. Louis Road	71
Chicago-Waukegan Road	11
State-Aid Work	28
	190

In addition contracts were awarded in 1920 for 134.95 miles of grading and 81 bridges on the bond issue system, the total cost of which will be about $3,427,000. Of these contracts 56.77 miles grading and 30 bridges have been completed.

According to a recent bulletin issued by the State highway department the effort put forth by the department and the contractors would easily have built double the mileage if conditions had been favorable. At the beginning of the season there were approximately 100 paving machines on hand waiting for materials to be delivered to them. On account of the car shortage and restrictive rulings of the Interstate Commerce Commission not more than 53 of these machines were in use at any one time during the season, and the average was considerably under that number.

The department warmly commends the contractors for their earnest efforts to conform strictly to the specifications and to produce roads of good quality despite the unfavorable conditions with which they had to contend. In many instances the increased cost of labor and materials caused by the car shortage meant the absorption of all their profits and in some cases even a direct loss.

MAINTENANCE COSTS.

The cost of maintaining the hard surfaced roads of the State in 1919 is shown in the table on this page. The table shows separately the cost of maintaining the surfaces and the shoulders and ditches and the combined maintenance cost for the whole roadway. The 1920 costs have not yet been tabulated. In some instances they will exceed the 1919 figures because of the higher costs of material and labor and the necessity for repairing breaks in all types of pavement due to excessive loading.

In interpreting the table of maintenance costs the department says:

"It should be understood that a one-year record of the maintenance cost of any particular type of construction is not necessarily a measure of the economic service value of that type. This is true because of the fact that certain types of road, such as bituminous macadam, may require but very little maintenance expenditure during one season, and the following season it may be necessary to give the road a surface treatment at a very considerable cost in order to preserve its integrity. This is not only true for the type of road mentioned, but is more or less true for all types. Further, if a certain type of pavement designed for, and used by, light traffic is suddenly called upon to bear heavy motor truck traffic, the pavement may be utterly destroyed so that it has to be replaced by an entirely different type to resist the altered traffic. The reconstruction is not ordinarily classed as maintenance but as new construction. This, of course, may lead to a misconception of the service rendered by a given type of pavement. Moreover, if but a small mileage of a given type of pavement is under maintenance, an unusually large expenditure on one section may cause the average for that type of pavement for one year to appear abnormally high. On the other hand, the location of the roads of a given type may be such that the total mileage of that type is subjected to unusually light traffic, and the maintenance cost, therefore, may appear abnormally low. These things must be kept in mind in connection with the table of costs presented."

LOCATING THE BOND ISSUE ROUTES.

During the past two years the greater part of the bond issue system of roads has been definitely located. This is a work that has consumed a large part of the time of the department, both in making reconnaissance surveys and in hearings held prior to determining upon locations.

The realization of the great value of the roads to communities and to farm residents has brought about very bitter contests over road locations in many places in the State, and in some instances has caused keen disappointment to the unsuccessful contestants. The department, in all cases, has rendered its decision only after the most thorough engineering study and careful consideration of all factors involved.

ROAD EXPERIMENT PLANNED FOR 1921.

In order to provide a basis for the solution of the questions of road strength which have been brought up by the motor truck, the department has entered upon the construction of a test road, in cooperation with the Bureau of Public Roads. The road will be completed early in the summer of 1921, and the tests will be made immediately following its completion. It is believed that the results obtained will give a very definite idea of the value of the different types and thicknesses of pavement for carrying truck loads, and also what limits shall be applied to the weight of vehicles which are permitted to use the roads.

Maintenance costs, Illinois roads, 1919 (all widths from 10 to 18 feet included).

Type.	Miles.	Wearing surface.		Upkeep of roadsides, etc.		Total maintenance.	
		Cost.	Average cost per mile.	Cost.	Average cost per mile.	Cost.	Average cost per mile.
Brick	86.90	$3,704.13	$42.63	$6,618.57	$76.16	$10,322.70	$118.79
Portland cement concrete	366.15	19,793.42	54.05	35,081.94	95.81	54,875.36	149.86
Bituminous concrete	19.43	4,745.94	244.75	230.77	11.88	4,976.71	256.13
Bituminous macadam	24.02	6,101.43	254.01	1,769.61	73.67	7,871.04	327.68
Waterbound macadam	26.95	8,070.32	299.45	952.73	35.35	9,023.05	334.80
Gravel	42.36	5,474.68	129.24	1,090.19	25.74	6,564.87	154.98
Oiled earth	133.50	8,460.51	63.37	2,820.33	21.13	11,280.84	84.50
Earth	280.75	21,529.11	76.69	4,382.56	15.61	25,911.67	92.30
Total	980.06	77,879.54	.....	52,946.70	.....	130,826.24	.....

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS.

*Report of the Director of the Office of Public Roads for 1916. 5c.
*Report of the Director of the Office of Public Roads for 1917. 5c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.

DEPARTMENT BULLETINS.

Dept. Bul. *105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
*230. Oil Mixed Portland Cement Concrete. 10c.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
*660. Highway Cost Keeping. 10c.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.
Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. *338. Macadam Roads. 5c.
505. Benefits of Improved Roads.
597. The Road Drag.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-Span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir. *89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States. 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
Vol. II, No. 15. State Highway Mileage and Expenditures in theUnited States in 1918. 15c.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D- 2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cement.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D- 4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D- 6. A New Penetration needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced Concrete Slabs Under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

Public Roads

VOL. 3, NO. 36 WASHINGTON, D. C. APRIL, 1921

THE RIDGE ROUTE, CALIFORNIA

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1921

Owing to the necessarily limited edition of this publication it will be impossible to distribute it free to any persons or institutions other than State and county officials actually engaged in the planning or construction of highways, instructors in highway engineering, periodicals upon an exchange basis, and Members of both Houses of Congress. Others desiring to obtain "Public Roads" can do so by sending 15 cents for a single number to the Superintendent of Documents, Government Printing Office, Washington, D. C.

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

PUBLIC ROADS

TABLE OF CONTENTS

Page.

Outstanding Features of Report of California Highway Study 3

9,231,941 Motor Cars and Trucks Registered by the States in 1920 . . 21
Andrew P. Anderson.

Resurface Concrete Road with Reinforced Concrete 29
T. M. Keene.

Federal-Aid Allowances 30

THOMAS H. MacDONALD . . . . . Chief of Bureau
P. ST. J. WILSON . . . . . Chief Engineer
H. S. FAIRBANK . . . . . Editor

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
SUBSCRIPTION PRICE, $1.50 PER YEAR

OUTSTANDING FEATURES OF REPORT OF THE CALIFORNIA HIGHWAY STUDY

THE report of the Bureau of Public Roads on the study of the California highway system, undertaken in July, 1920, at the request of the California commission, was published in March by the commission. The report is divided into three parts, headed respectively, "Data," "Discussion," and "Conclusions." It is illustrated with numerous photographs and diagrams, which, however, represent only a small part of the 7,500 photographs and other data, which, it is stated, are on file in the Bureau of Public Roads.

The foreword by Thomas H. MacDonald, Chief of the Bureau of Public Roads, follows:

An adequate review of the results which have been secured by the development of any system of State highways must follow to-day an uncharted course. The essentials and nonessentials of such a task have not yet been sufficiently classified to avoid the gathering, on one hand, of material which modifies only slightly the final conclusions, or, on the other, to insure that all vital data and information is secured.

The California study is the most comprehensive study of results obtained through the development of a State highway system that has yet been undertaken. The work of this study has followed two principal lines; one that includes those questions that are engineering in character, and the other those that are economic in character. These two groups of questions are so interrelated and so interdependent that they can not be separated. All road improvement is a means to an end—improved transportation facilities. The proper development of such facilities ought to be based on both the engineering and economic considerations involved. But the practical application of these considerations is always modified by the attitude of the public.

For the purpose of this study, the principal operation was to classify all the pavement laid. This classification covered 1,262 miles, from which a complete record of condition of all concrete pavement for each one-tenth mile resulted and is supported by 7,500 consecutive photographs filed in the bureau. It is recorded completely by diagram. Associated with this classification there were drilled 638 cores through the pavement at intervals on 800 miles of the highway between Red Bluff and San Diego; 481 of these cores were tested and all were carefully examined and measured. A large number have been photographed for this report.

Twleve special, intensive studies of failed portions of the road surface resulted in a great volume of data which can only be summarized in the report, but which clearly establish in practically every instance the nature and cause of the defective pavement.

In connection with the many selected special studies, soil moisture determinations were made for cross sections of the road by borings at close intervals. Tests for moisture content, moisture equivalent, and for shrinkage were made at the laboratory of the University of California.

A complete classification of the subgrade soil under all the pavement on the State highway system was made by soil experts and plotted on the pavement condition diagrams. Below each concrete core, samples of soil were also removed and tested.

A State-wide traffic census was taken at 103 stations for an equivalent 16-hour week day, and many Sunday and supplementary counts were also taken. This traffic record revealed the amount and character of travel for the summer interval on the State highways. It has resulted in a set of traffic diagrams from which the total annual duty of the California highway system has been estimated, and also the corresponding revenue, or the operating income to the community.

Supporting the traffic count, extensive field studies were made of the producing agricultural areas for nine groups of agricultural crops and the peak load in tons and the peak interval in time for these crops was determined. This study covered the main valleys of the State.

During the progress of field investigation there were carried on at Sacramento a complete audit and analysis of all the books of the State highway commission office. This work resulted in a satisfactory and complete distribution of all costs of surveying, construction, engineering, and maintenance, and produced summaries that account for practically every dollar made available for the use of the commission.

Painstaking efforts have been made to secure all the data necessary to present the conclusions impartially and uncolored. There is much of value in the record to be made available after more research.

Within the past five years an unprecedented demand has been made upon the highway administrator and highway engineer to produce a large mileage of economical and serviceable highways. The extent to which he has produced this combined result is the true standard of measurement of his achievement.

Let the present traffic service rendered by the State highways of California, conservatively estimated, we believe, at 400,000,000 vehicle-miles per year be multiplied by any reasonable unit rate to indicate the present annual returns to the people on the total investment to date of about $42,000,000.

Now turn to one paragraph from the report selected as the most vital to be repeated here:

"The financial administration has been scrupulously honest and careful and the administrative and engineering costs have not been excessive, nor have final costs much exceeded the engineer's estimates."

There should be no hesitation in going forward with confidence.

The bureau gratefully acknowledges the cooperation and assistance extended by the Bureau of Soils of the Department of Agriculture, the Bureau of Standards of the Department of Commerce, the University of California, the California Highway Commission, and the highway engineer.

The field studies and the preparation of this report were carried forward under the immediate direction of Dr. L. I. Hewes and T. Warren Allen, general inspectors of the Bureau of Public Roads.

After a short historical sketch the report discusses the systems designed and the organization of the department with a complete presentation of the necessary tax requirements under the three bond issues. It is pointed out that the State highway system reflects the system laid out by the old bureau of highways in 1895, and is an excellent system of through trunk and market roads. The statement of the condition of the funds shows receipts of $42,007,330.07 and expenditures to July 1, 1920, of $41,790,884.

The report shows that of the total system of 5,360 miles laid out under the three bond issues, there have been graded and completely paved 1,345.4 miles and 377.1 miles have been graded and not paved. A length of 319.4 miles was in process of grading and not to be paved, and 206.8 miles were still in process of paving with Portland cement concrete, all on July 1, 1920. Of the paving 765 miles is Portland cement concrete unsurfaced, and 480.7 miles is surfaced with three-eighths inch of bituminous material and pebbles; 53.9 miles of concrete have been surfaced with Topeka and 4.2 miles with Willite. There are 33.8 miles of oil macadam. The total actually constructed to date is 1,930 miles.

There is a tabulated statement, arranged by division, routes, counties, and sections, showing as of July 1, 1920, details of type and costs of survey and construction. This table, covering all the contracts and all the day-labor jobs since the beginning of work in 1912, was made from an analysis and audit of the commission's books at Sacramento. It is shown that the total overrun on all construction was only 6.24 per cent above the engineer's estimate. The direct payment for labor and materials totaled to July 1, 1920, $30,936,871. On this construction the cost of surveys, engineering, and administration was 15.86 per cent.

The report contains a detailed table of Federal-aid postroad construction which shows that there have been approved for construction 221.34 miles of concrete pavement at an estimated cost of $5,081,562, 135.26 miles of graded earth road at an estimated cost of $1,801,762, one bridge estimated to cost $285,493, and 4.08 miles of gravel road estimated to cost $37,136.

There is a chapter on bridges and structures, with a detailed list of certain noteworthy and typical bridges.

It is shown that the State has expended from the motor-vehicle fund for maintenance, improvements, and reconstruction $5,780,551, and that the overhead and indirect charges on this work approximate 19.2 per cent, overhead alone 12.5 per cent. Tables of maintenance by types and divisions showing separate expenditures for general maintenance, improvement, and reconstruction are presented, also a table showing the detailed cost of construction and maintenance of oil-macadam roads. It is shown further that maintenance of the typical 15-foot by 4-inch concrete road costs $0.006 per square yard per year and for concrete constructed with three-eighth-inch oil top $0.009 per square yard per year on an average.

PRESENT CONDITION OF CONSTRUCTED ROADS.

The classification of the condition of the existing concrete pavement in the State for each one-tenth mile divides the roads into the following six classes:

(A) Pavement in which the plainly visible transverse cracks do not exceed the normal number expected of a pavement constructed without expansion joints, and which has no plainly visible longitudinal cracks.

(B) Pavement having more than the normal number of plainly visible transverse cracks or with some "crowfoot" cracks at the edges, or with both.

(C) Pavement similar to classes A and B with one plainly visible longitudinal crack or with a considerable number of "crowfoot" cracks.

(D) Pavement so cracked transversely and longitudinally that numerous slabs are formed of less area than in class C but that do not average less than about 50 square feet.

(E) Pavement in which the plainly visible transverse and longitudinal cracks are so numerous that it is broken into slabs having areas less than about 50 square feet but in which no general disintegration appears.

(F) Pavement badly broken and with disintegrated portions.

TABLE 1.—*Showing all classified concrete pavement built by the State (surfaced and unsurfaced).*

Class.	Year built.																Total.	
	1913		1914		1915		1916		1917		1918		1919		1920			
	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.	Miles.	Per cent.
A	2.83	13.8	71.35	42.5	139.33	39.7	73.38	24.8	6.65	11.3	37.54	30.0	53.91	32.6	33.24	42.9	418.23	33.0
B	5.85	28.6	63.75	38.0	106.35	30.3	119.62	40.5	26.29	44.4	49.50	39.6	66.78	40.4	37.32	48.2	475.46	37.7
C	3.85	18.8	18.27	10.9	68.17	19.4	53.41	18.1	15.28	25.8	24.37	19.5	23.90	14.4	4.15	5.4	211.40	16.7
D	1.83	9.0	2.67	1.6	14.65	4.2	32.59	11.0	8.66	14.6	10.24	8.2	12.20	7.4	1.60	2.1	84.44	6.7
E	.10	.5	.40	.2	3.15	.9	11.55	3.9	2.29	3.9	3.29	2.66	8.23	5.0	1.00	1.3	30.01	2.4
F	6.00	29.3	11.50	6.8	19.14	5.5	5.13	1.7	0.00	.....	.05	.04	.25	.2	.10	.1	42.17	3.4
Total	20.46	100	167.94	100	350.79	100	295.68	100	59.17	100	124.99	100	165.27	100	77.41	100	1,261.71	100
Per cent of total each year	1.7	.....	13.3	.....	27.8	.....	23.4	.....	4.7	.....	9.9	.....	13.1	.....	6.1	.....	100	.....

RELIEF MAP OF CALIFORNIA SHOWING STATE HIGHWAY SYSTEMS FOR 1909, 1915, AND 1919.

The field classification was made with State highway layout books in hand showing each section and with miles measured by an automobile odometer. The classification notes were supported by 7,500 photographs taken at standard intervals of from one-tenth to one-half mile. From the field notes and the photographs, class-condition diagrams were developed for each State highway route, county, and section, and these plots were again checked by field inspection with the diagrams in hand. The classification result is given by the summary in Table I which shows that 12.5 per cent of the pavement on July 1, 1920, was found to be in classes D, E, and F, and the balance, or 87.5 per cent, in classes A, B, and C.

SAMPLE CORES DRILLED FROM THE CONCRETE PAVEMENT. THE NUMBERS ON THE PLACARDS IDENTIFY THE CORES. THE WHOLE NUMBER 4 IN THE UPPER NUMBER INDICATES THAT THE CORES WERE TAKEN ON ROUTE 4; THE DECIMAL FIGURE IS THE NUMBER OF THE CORE. THE LOWER FIGURE IS THE LABORATORY NUMBER. THE WHITE LINE ON THE SCALE INDICATES A HEIGHT OF 4 INCHES.

The condition diagrams were plotted on a horizontal scale of 2 miles to the inch and to an arbitrary, uniformly graduated, negative vertical scale showing five classes, B to F, inclusive, by tenths of a mile.

SAMPLE CONCRETE CORES.

For the purpose of determining the condition of the concrete actually in place, sample cores were drilled from approximately 800 miles of the pavement. In all, 638 4½ inch cores were drilled. One hundred and eighty-seven cores were drilled with the chilled-shot type of drill and the remainder with the diamond drill. The cores were shipped each night to the laboratory of the United States Bureau of Standards in San Francisco, where 481 were subjected to the following tests:

1. Inspection, with record of appearance.
2. Photographed.
3. Measured.
4. Planimetered to determine approximately the percentage of coarse aggregate.
5. Water absorption.
6. Weight per cubic foot.
7. Compression.

The results of the tests showed that the cores varied considerably in respect to the maximum size of coarse aggregate, its distribution, the coarseness and the grading of the sand. The depth of concrete varied considerably but in general ran greater than the specified 4 inches. Not much variation in density appeared. The photographs of the cores checked the notes on inspection. Measurements showed a surprisingly close average of 50 per cent coarse aggregate in both the 1 : 2 : 4 and 1 : 2½ : 5 concrete. The absorption showed an average of about 1½ per cent. The weight per cubic foot varied from 140 to 160 pounds, with some marked deviation in a few instances. After compression test examination showed, with few exceptions, a sound coarse aggregate of crushed or uncrushed fragments of gravel. The report gives sample tracings of the coarse aggregate and a full table of the results of the compression tests, etc., and notes that while the average compression test when corrected for cylinders 9 inches high by 4½ inches in diameter averaged well above 3,000 pounds there is a slight decrease in compression strength with the age of the concrete.

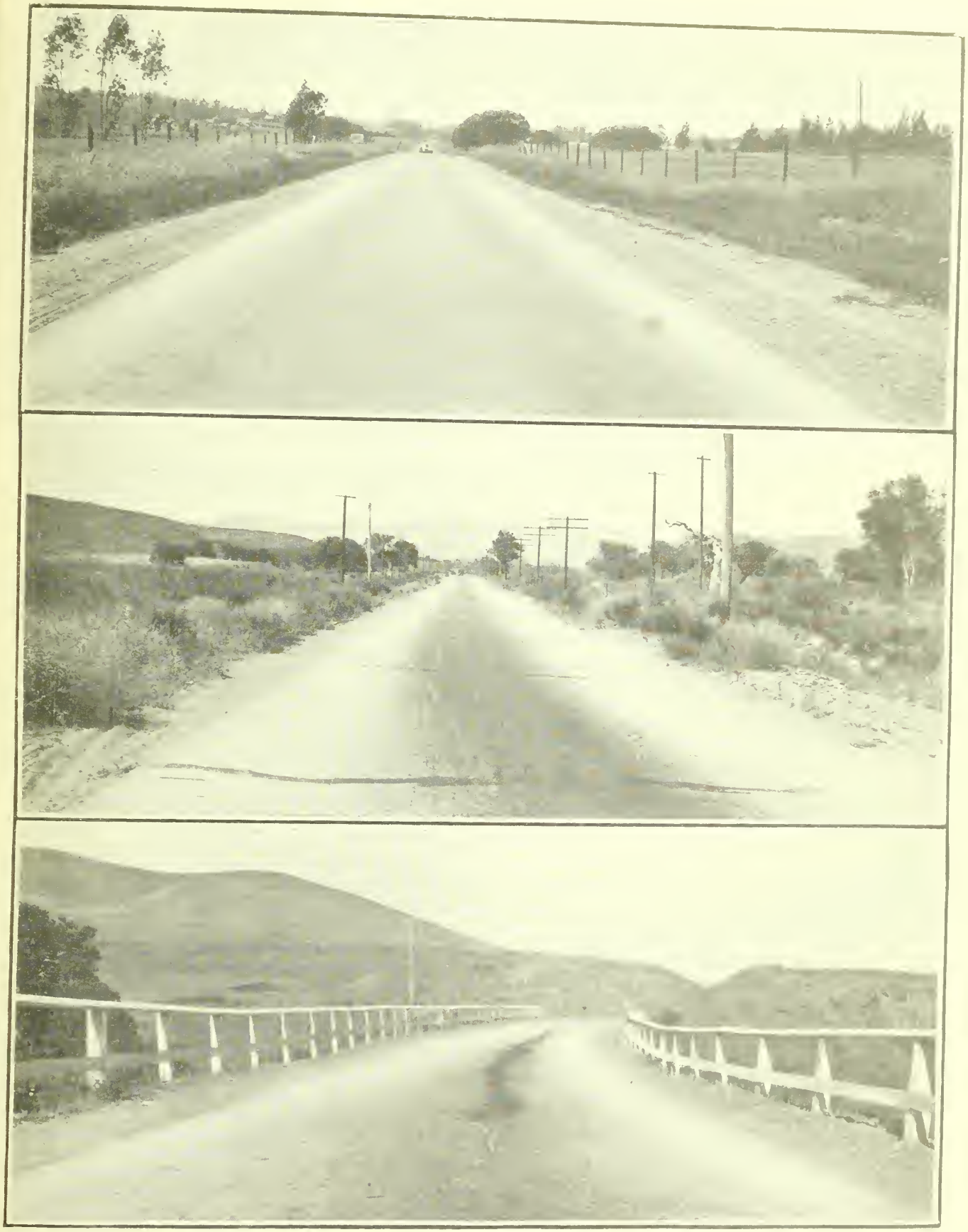
SUBGRADE SOILS.

In connection with the field classification of pavement, and with 12 special intensive studies, classification of the underlying subsoil was made with the cooperation of experts from the Bureau of Soils and the division of farm irrigation of the Bureau of Public Roads, all in the Department of Agriculture. The checked soil classification was plotted on the class-condition diagrams. The soil classification adopted was as follows:

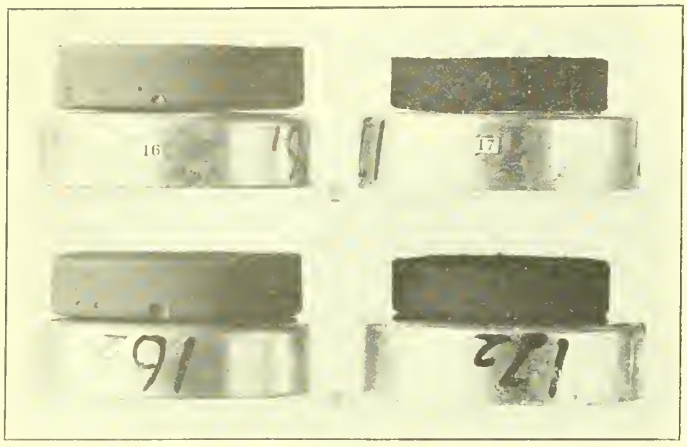
1. Clay and adobe soils (includes clay, silty clay, clay loam, and clay).
2. Marsh land (includes silt, marsh, and peat lands).
3. Loams (include loam, clay-loam, silt-loam, and silty-clay loam).
4. Sandy loam (includes coarse sandy loam, sandy loam, and fine sandy loam).
5. Sand and gravel.

The classification shows that approximately 70 per cent of the concrete pavement of classes D, E, and F occurs on soils of class 1.

Numerous moisture content and moisture equivalent determinations and shrinkage tests were made on soil



PAVEMENT CLASSES.
TOP, CLASS A; ROUTE 1, SONOMA COUNTY, SECTION C.
MIDDLE, CLASS B; ROUTE 4, LOS ANGELES COUNTY, SECTION A.
BOTTOM, CLASS C; ROUTE 2, SANTA BARBARA COUNTY, SECTION F.



SOIL SAMPLES TAKEN FROM ROUTE 1, SONOMA COUNTY, SECTION C.

samples from various parts of the State at the laboratory of the University of California and full tables of results are included in the report, also 13 cross sections of road plotted to show lines of equal moisture content in the subgrades.

ECONOMIC AND OTHER STUDIES.

The principal economic study consisted of a State-wide traffic census for one equivalent 16-hour day at 103 stations. The blanks used for counting traffic was subdivided into nine classes, as follows:

Light automobiles.
Heavy automobiles.
Busses.
Trucks less than 1 ton with pneumatic tires and less than $\frac{3}{4}$ ton with solid tires.
Trucks from 1 to $2\frac{1}{2}$ tons with pneumatic tires and from $\frac{3}{4}$ ton to $1\frac{1}{2}$ tons with solid tires.
Trucks from 3 to 5 tons with pneumatic tires and from 2 to 3 tons with solid tires.
Trucks, 5 tons and over, with pneumatic tires, and 3 tons and over with solid tires.
Horse-drawn vehicles.
Extra heavy vehicles.

Traffic was counted from 6 a. m. to 10 p. m. and the results are presented in a table the summary of which is given in Table 2. It is seen that for week days the total daily number of all vehicles averaged approximately 1,387, of which 2.7 per cent was horse-drawn traffic and 12.5 per cent truck traffic. The corresponding average Sunday traffic at 16 stations was 2,267 vehicles, of which horse-drawn traffic was only nine-tenths of 1 per cent and truck traffic 4.4 per cent (see Table 3). The report shows interesting statistics concerning traffic, including hourly variation for week days and Sunday and weekly variation.

A questionnaire was sent to 21,000 owners of solid-tire motor trucks which resulted in about 2,000 available replies, of which complete analysis was presented. A systematic study of the motor-bus traffic was also made and shows a total of 103 operating lines with an average of 610,747 passenger-miles daily on the State highway system. There was also an investigation of the motor-truck freight-carrying lines and a field study of the agricultural traffic. From the data developed it is estimated that at a 5-cent saving per vehicle-mile on State highway pavement alone the income to the State of California during the calendar years 1919 and 1920 has been $35,000,000. Complete text of the "Discussion" and "Conclusions" follows:

TABLE 2.—*Showing average 16-hour week-day traffic at 101 stations.*

Type.	Average vehicles per day.	Per cent of total traffic.	Per cent of total trucks.
Light automobiles	472	34.10	.....
Heavy automobiles	674	48.50	.....
Passenger busses	31	2.20	.....
Trucks, class 1	73	5.30	42.20
Trucks, class 2	41	3.00	23.70
Trucks, class 3	28	2.00	16.20
Trucks, class 4	29	2.10	16.80
Horse-drawn traffic	32	2.70	.....
Extra heavy traffic	2	.10	1.10
Total of all vehicles	1,387	100.00	100.00
Total of trucks only	173	.....	.....

1. Less than 1 ton with pneumatic and less than $\frac{3}{4}$ ton with solid tires.
2. One to $2\frac{1}{2}$ tons with pneumatic tires and $\frac{3}{4}$ to $1\frac{1}{2}$ tons with solid tires.
3. Three to 5 tons with pneumatic tires and 2 to 3 tons with solid tires.
4. Five tons plus with pneumatic tires and 3 tons plus with solid tires.

TABLE 3.—*Showing average 16-hour Sunday traffic at 16 stations.*

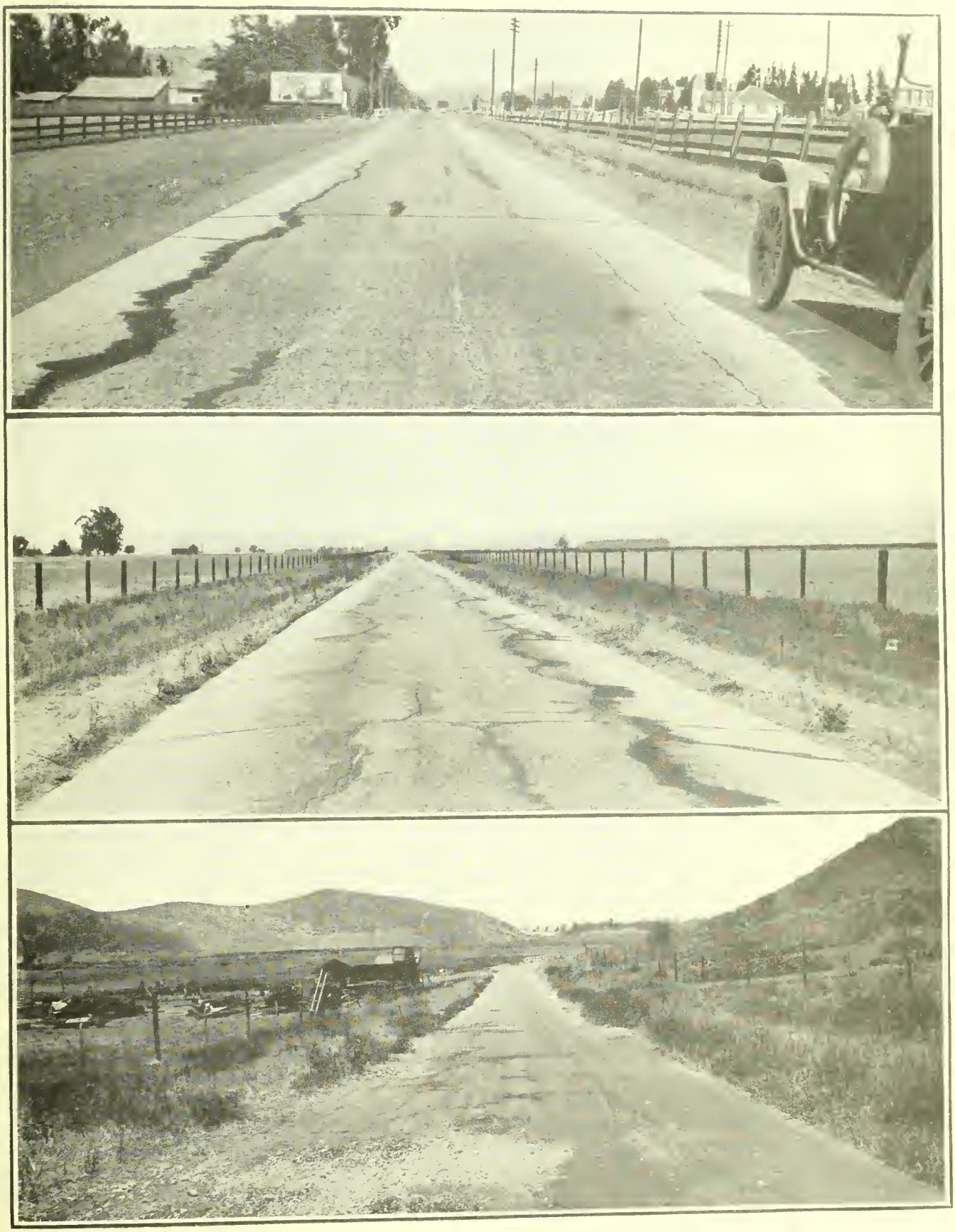
Type.	Average vehicles per Sunday.	Per cent of total traffic.	Per cent of total trucks.
Light automobiles	833	36.8	.....
Heavy automobiles	1,282	56.6	.....
Busses	29	1.3	.....
Trucks, class 1	62	2.7	50.5
Trucks, class 2	18	.8	14.6
Trucks, class 3	10	.4	8.1
Trucks, class 4	12	.5	9.7
Horse-drawn vehicles	21	.9	17.1
Extraordinarily heavy	.....	.....	.....
Total of all vehicles	2,267	100.0	100.0
Total of trucks only	123	.....	.....

BOND ISSUE, POLICY, AND SYSTEMS DESIGNED.

The system of 4,500 miles laid out in 1896 by the old State bureau of highways reached every county seat and traversed the main valleys. It was doubtless of value as a guide to the selection of the system of 5,560 miles now building—and the present system visibly reflects the original one.

Apparently the interval from 1896 to 1909 demonstrated the futility of attempting to create an adequate system of State highways by small special appropriations for selected roads.

The State highway bond issue of 1909–10 had been preceded by an issue of $1,250,000 in San Diego County and of $3,500,000 in Los Angeles County and by highway bond issues in Eastern States. The deferred serial type of bond chosen was in accord with the best practice, but the term of 45 years for the longest serial is unnecessary and will require a corresponding excessive total interest payment. The legal provisions fixing both the nominal interest and the sales price proved embarrassing to the highway commission. There is



PAVEMENT CLASSES.

TOP, CLASS D; ROUTE 8, SOLANO COUNTY, SECTION A.
MIDDLE, CLASS E; ROUTE 7, SOLANO COUNTY, SECTION D.
BOTTOM, CLASS F; ROUTE 2, VENTURA COUNTY, SECTION B.

38498—21——2

every evidence that the bonding principle itself at this period was sound.

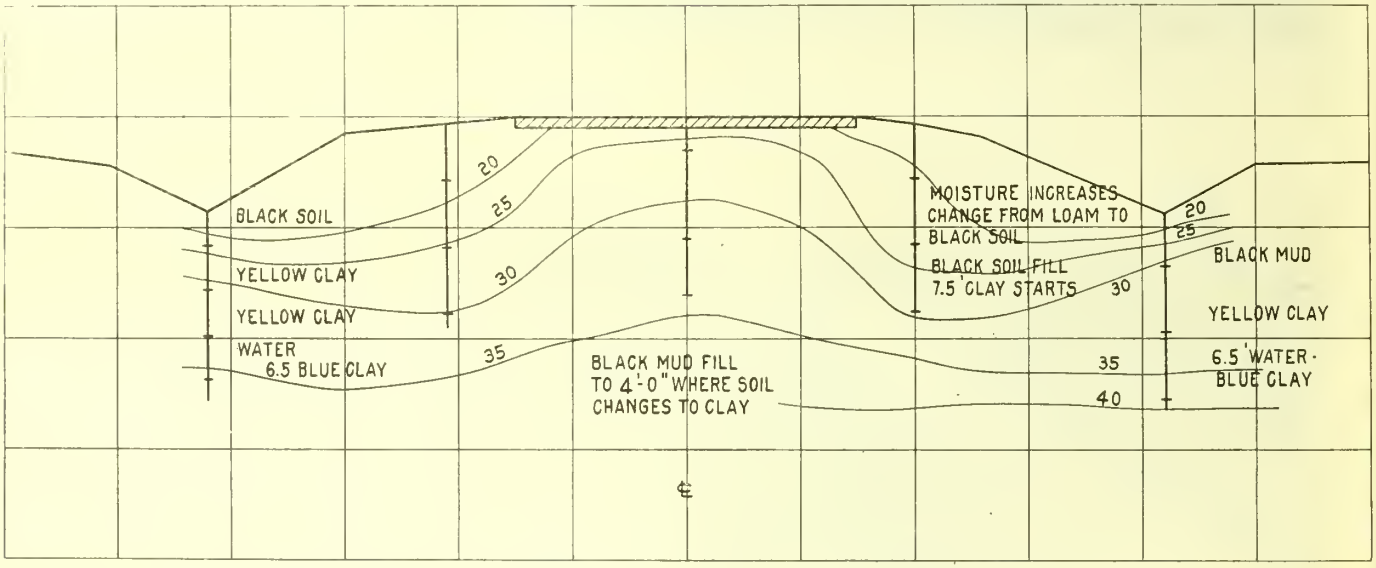
The highways act of 1909 created by implication a system of 3,082 miles, which was manifestly far in excess of the possible construction with the fund of $18,000,000 provided. The influence of this discrepancy has been far reaching. Tne State highway commission stated in their final report, "Notwithstanding the admittedly impossible task the commission endeavored by the employment of every honorable expedient to obtain the greatest possible return in roads for the money."[1]

Actually 1,300 miles, including graded roads, were built from the proceeds of the first bond issue.

The system of roads laid out under and by the various laws is an excellent one and the portions built by the commission prior to January, 1917 (when the funds of the first bond issue were exhausted), appear, in general, to have been most needed. The distribution and the order of this first construction may have been conditioned by necessary policy. Under the legal restriction governing the sale of bonds it became necessary for various counties to buy the bonds, and naturally roads in those counties which bought took some precedence. Counties were also obliged to pay the interest charges on the funds used for highways within their boundaries, and some of the poorer counties were not easily able to do this. In order to make the bond money go as far as possible the commission also influenced the various counties to furnish the necessary expensive bridges and rights of way, which action created some opportunity for preference in construction. In addition to these influences, which conditioned the distribution of construction, it was doubtless good policy to acquaint as many voters as possible with the proof of the advantages of improved roads by actual examples.

The success of the initial policy of the commission with respect to type of road and distribution of construction is evidenced by the increased majority for the second bond issue of 1915; and the still larger majority for the third issue of 1919 is evidence of its continued success.

The general policy of the commission, especially with respect to the order of construction, in attempting to carry out the terms of the laws which conditioned the sale of bonds and implied or prescribed excessive mileage to be built, must be judged by its progressive reaction on the whole State rather than by comparing it with other alternative policies that may now be apparent to a State community enlightened by the benefits of the improved roads. Such a possible alternative policy, for example, might have given priority to the trunk road from Los Angeles to San Francisco.



CROSS SECTION SHOWING SOIL MOISTURE CONTENT ROUTE 1, HUMBOLDT COUNTY, SECTION G.

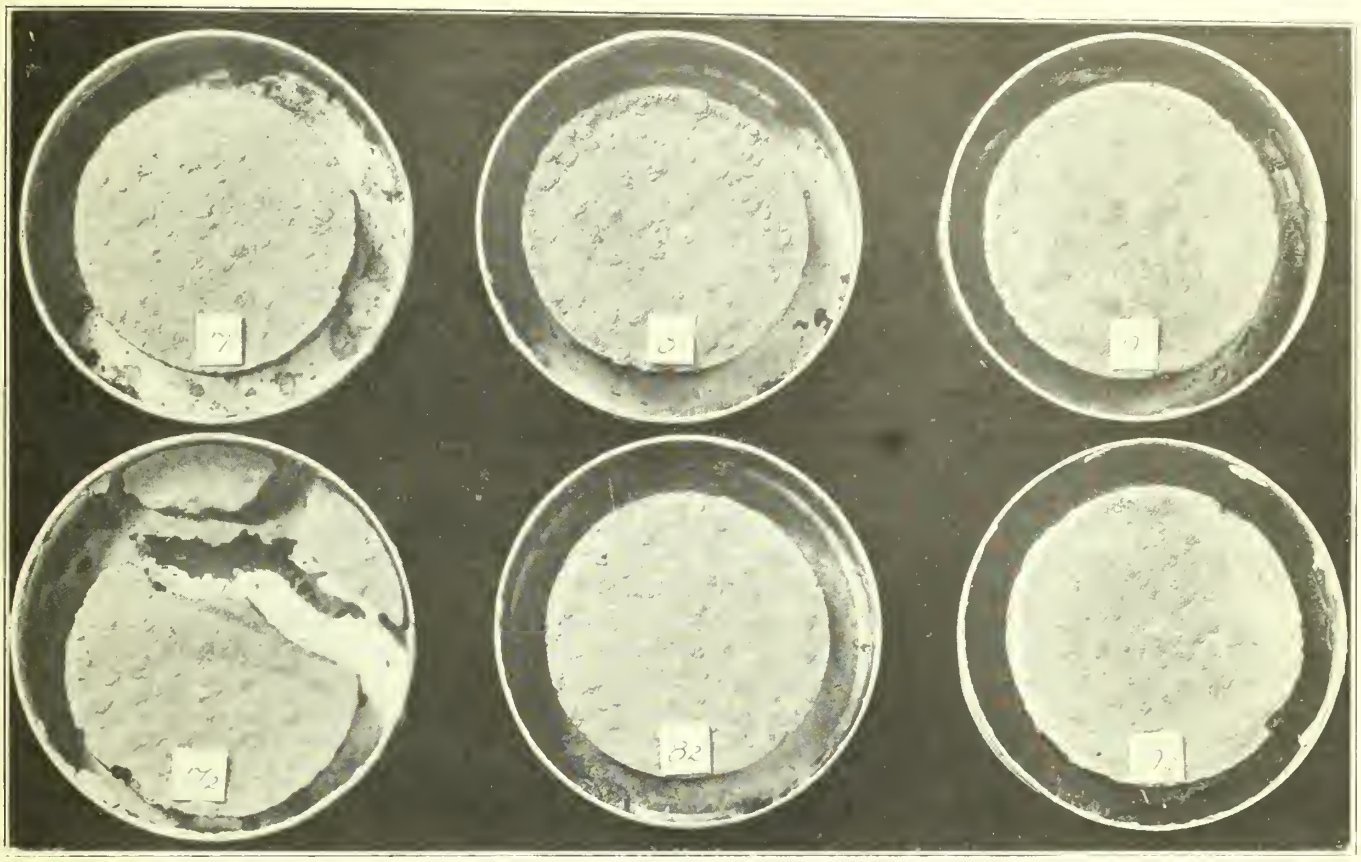
MANAGEMENT.

The actual construction work of the commission was also conditioned by the highway act (*a*) in respect to its permanent character and (*b*) by the first implied order for more than 3,000 miles of highway.

The commission obviously attempted to combine the element of durability in design with rapid extension of mileage. Although the money was theoretically available after the fall election of 1910, no construction was started until August, 1912. There were, theoretically, sufficient funds to allow large planning of the work and the commission took advantage of the opportunity to conduct business on a big scale. They began work deliberately.

In the fall of 1911 they made a comprehensive tour of the State with the highway engineer and established 7 divisions. On the 21st of October, 1912, they signed

[1] First Biennial Report of the Californ ¡ɐ Highway Commission, Dec. 31, 1918, p. 40.



SOIL SAMPLES TAKEN FROM ROUTE 5, ALAMEDA COUNTY, SECTION B.

contracts with the Natomas Consolidated of California (a corporation) for 500,000 tons of crushed cobbles at 45 cents per ton, f. o. b., and also contracts with the Russian River Gravel Co. and the Grant Gravel Co. for 175,000 tons of screened gravel at 27½ cents per ton, f. o. b. These were low figures for concrete aggregates and the commission states: "Tended to fix a low price, which had its influence on other producers of concrete aggregates." [2]

Effective October 30, 1912, the commission secured from the Southern Pacific Railroad Co. a local freight tariff for commodities "consigned to and for use by the California Highway Commission" at substantially one-half the prevailing rates. These rates were extended by tariff No. 742-C, one year later.

In the purchase of cement the commission states: "Under unwritten agreement the companies agreed with the commission that during the life of the work the price should not exceed $1.40 per barrel at the mills. This special price, far below the general market price, was made to encourage the use of cement in highway construction."[2] The actual yearly purchases of cement to July 1, 1920, with net prices, are tabulated below:

Year.	Barrels purchased.	Average mill base.	Cost at mill.
1912	142,465.50	$1.240	$176,683.24
1913	242,514.40	1.309	278,376.36
1914	677,790.05	1.325	898,403.48
1915	355,005.50	1.367	485,267.31
1916	110,090.00	1.371	150,958.28
1917	220,794.00	1.454	321,064.61
1918	221,418.00	1.621	359,036.76
1919	231,737.00	2.038	451,270.72
1920 (up to July 1)	43,048.00	2.158	89,699.56
Total and average	2,244,862.75	1.443	3,249,780.32

After the first bond issue of $18,000,000 was exhausted, the cement companies felt that their obligation should end.

When the railroads came under national jurisdiction during the war the preferential freight rates were abolished. On account of difficulty of delivery due to war conditions, which resulted in (valid) claims by the contractor and required stock piling at times, and due to the general rise in prices, the commission has temporarily discontinued to supply materials. They state that during the war the work progressed with increasing difficulty due to high costs, open-top car embargo, lack of bidders, restriction of the Capital Issues Committee and the United States Highway Council, but did not stop. The total of administration, engin-

[2] First Biennial Report of the California Highway Commission, p. 39.

eering, and other overhead costs are very reasonable with the possible exception of the total overhead on maintenance.

STANDARD PAVEMENT DESIGN.

The standard design adopted for the surface was a concrete "base" of 4 inches with a three-eighths-inch wearing surface of asphaltic oil and pebbles. The concrete mix was 1 : 2½ : 5 and the width was 15 feet with 3-foot earth shoulders.

Although the concrete surface was doubtless originally laid as a base, only approximately 43 per cent has been given the oiled surface. The average price of $1.14 per square yard obtained in the earlier years for the 4-inch 1 : 2½ : 5 concrete, including grading and structures, was remarkably low. This price was equivalent to about $10,000 per mile of completed 15-foot road and compared very favorably with the similar price of $1.21 per square yard for oil macadam. Neither price includes either indirect charges or overhead. The corresponding average price for the 4-inch 1 : 2 : 4 concrete laid since 1917 has been $1.84, which is also low. The concrete pavement has probably produced a smoother and more satisfactory riding surface than any of the other types incidentally laid.

This concrete pavement is the thinnest that has been extensively laid in any State and would have been rejected as too thin in any State subject to winter frosts. It is 1 foot narrower than the minimum width of concrete roads built in most other States, and it is believed that under present conditions it is in general 3 feet too narrow. The original mix of 1 : 2½ : 5 was leaner than that extensively used in other States and the present mix of 1 : 2 : 4 is not as rich as usual in several States, but it is believed to be adequate for the traffic. In this connection it is to be observed that California was the pioneer State in adopting concrete as the standard pavement for the State highway system.

The function of the three-eighth-inch asphaltic oil wearing surface or "skin top" has not been completely determined. That it is not a necessary element of construction is evident from a comparison of the service and condition of bare and covered concrete which now exists. It was probably considered that the asphaltic oil top would (*a*) take the wear of travel from the concrete, (*b*) protect to some extent the concrete base from impact, and (*c*) prevent the penetration of water through such cracks as occurred. It has not been observed that the bare concrete itself shows evidence of wear by rubber-tired traffic, which is now almost exclusively the traffic throughout California. Trucks with solid tires, however, cause disintegration at open cracks. It is doubtful if a three-eighth-inch bituminous layer materially lessons impact. A comparison of the data presented in the tables of classification and in the summary class diagram shows that the condition of the pavement covered with asphaltic oil top compares favorably with the bare concrete, but it is noted that because of the presence of the asphaltic oil top the classification of the concrete base beneath was made difficult and in all probability was higher than it would have been had the concrete base been uncovered throughout. To some extent the asphaltic top has sealed the concrete from water during the rainy periods and possibly it has thus prevented softening of the subgrade. It has cost about 8 to 9 cents per square yard and requires considerable repair and renewal, and under nonabrasive rubber-tired traffic it is not believed that it serves a purpose commensurate with its cost. It is more slippery in wet weather than is bare concrete.

The 4-inch plain concrete of lean mix has proved in places very durable. There are 580 (distributed) miles built prior to 1917 that are of classes A and B. Under adverse conditions, particularly of soil, it is evident, however, that a pavement of such thinness has a very low safety factor and is inadequate. Its use has now been abandoned and a minimum thickness of 5 inches of reinforced concrete is required.[3] The original construction produced considerable rough surfaced concrete which, as traffic developed doubtless materially increased impact. On the narrow 15-foot pavement loads passing each other necessarily traveled close to the edge. "The crowfoot" defects are doubtless due to such travel of trucks when the conditions were unfavorable. There is little, if any, decisive evidence that reinforcing introduced in the 4 or even in the 5 inch concrete (particularly of the triangular mesh variety) has proved effective on adverse soils or under combinations of adverse subgrade and traffic. Nor will the widening of a 4-inch pavement to 20 feet eliminate the "crowfoot" cracks which are observed on such width concrete, even in instances on sandy soil.

ORIGINAL DESIGN NOW HAS LOW FACTOR OF SAFETY.

The original concrete pavement design, in short, now has little or no factor of safety and under unfavorable conditions has not withstood the internal stresses produced by traffic flexure and variations in temperature and subsoil moisture. It is doubtful if such a safety factor can be introduced without considerably increasing the mass of concrete. It appears that under adverse soil condition there is considerable flexure with traffic.

To introduce sufficient steel to prevent flexure of a 4-inch or even 5-inch pavement over a shrunken or wet subgrade, or even a loose sandy subgrade is probably a doubtful economy. The existing longitudinal cracks that are accompanied by any separation or by "faulting" along the crack, or by displacement, are evidences of subgrade displacement or settlement or uneven subgrade shrinkage as a primary cause. Such defects are typical either with a single center crack or two longi-

[3] General Orders, 421 and 427, May 1 and Sept. 15, 1920, respectively.

tudinal quarter cracks and the soil moisture sections attached to the report appear to confirm this behavior.

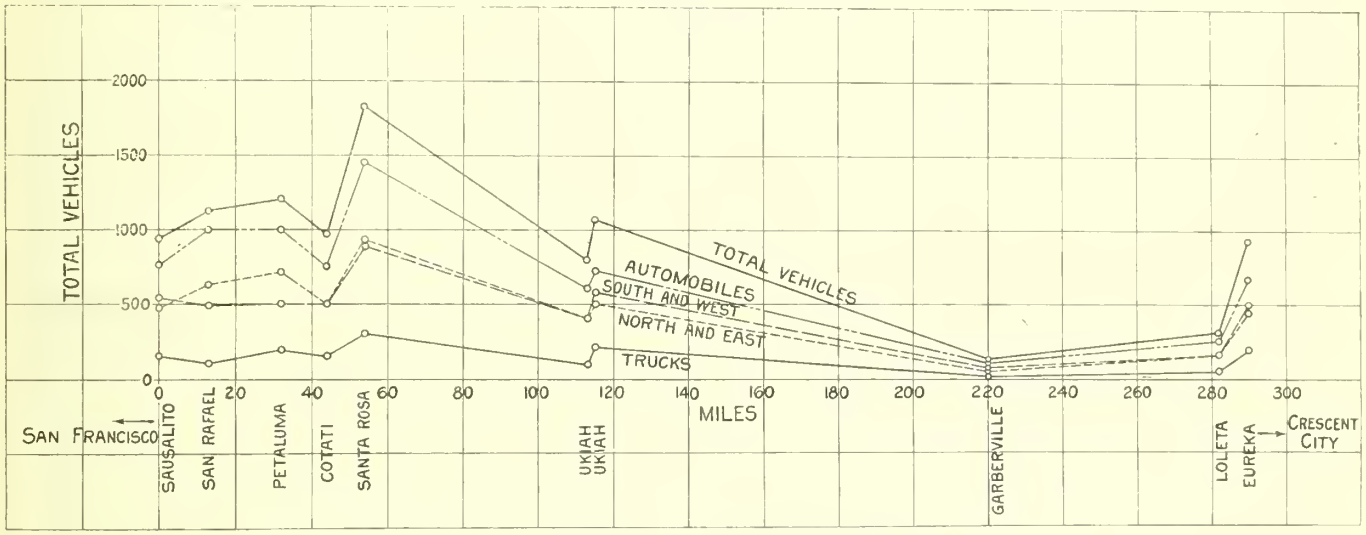
Some special treatment of adverse subgrade soils, particularly of class 1, will be necessary. Capillary action and high moisture retentiveness and violent shrinkage must be met. The amount of admixture or the thickness of protective layers of noncapillary and supporting soils is not yet known. A flat subgrade might help to a slight extent to counteract such defects by eliminating some transverse tension due to normal pressure. The crown of $2\frac{3}{4}$ inches in the present 15-foot standard design may well be reduced is to $1\frac{3}{4}$ inches and with a flat subgrade and an added $1\frac{3}{4}$-inch maximum thickness there is an added factor against center longitudinal cracks.

By January, 1917, the State highway commission had constructed a total of 835 miles, mostly of 4-inch by 15-foot concrete pavement. They continued to build the same type except that the mix was increased to 1:2:4. In the light of the increase in thickness and the addition of reinforcing steel rods in 1920, it must now be inferred that the commission was again in 1917 governed in policy by the necessity for increased mileage. They say with reference to the second bond issue: "The untoward condition accompanying the World War soon set at naught the expectation of completing the State highway system with the proceeds of the second bond issue and the commission for the second time confronting an impossible task is again forced to secure the greatest value receivable with the funds at its command." This bond issue was based upon estimate furnished from 1914–15 figures.

It is noted that the standard plans do not provide for widening the pavement or curves, although some widening of the "lune" type has been done subsequent to construction. The cross sections are in general noticeably "shallow" or "tight" and require a minimum amount of excavation. However, in the northern part of the State particularly, the climate appears to demand more pronounced drainage than has resulted from the present design. The sections do not provide for very pronounced superelevation, which is now frequently and successfully made one-half inch to 1 inch to the foot in many States. It is believed that the width of the main roads should be increased from the present width of 21 to 24 feet to a width of from 24 to 30 feet, except in heavy cuts. The crowns, as has been noted above, could well be reduced to $1\frac{3}{4}$ inches even on a wider pavement.

DESIGN OF GRADE, ALIGNMENT, AND SECTIONS.

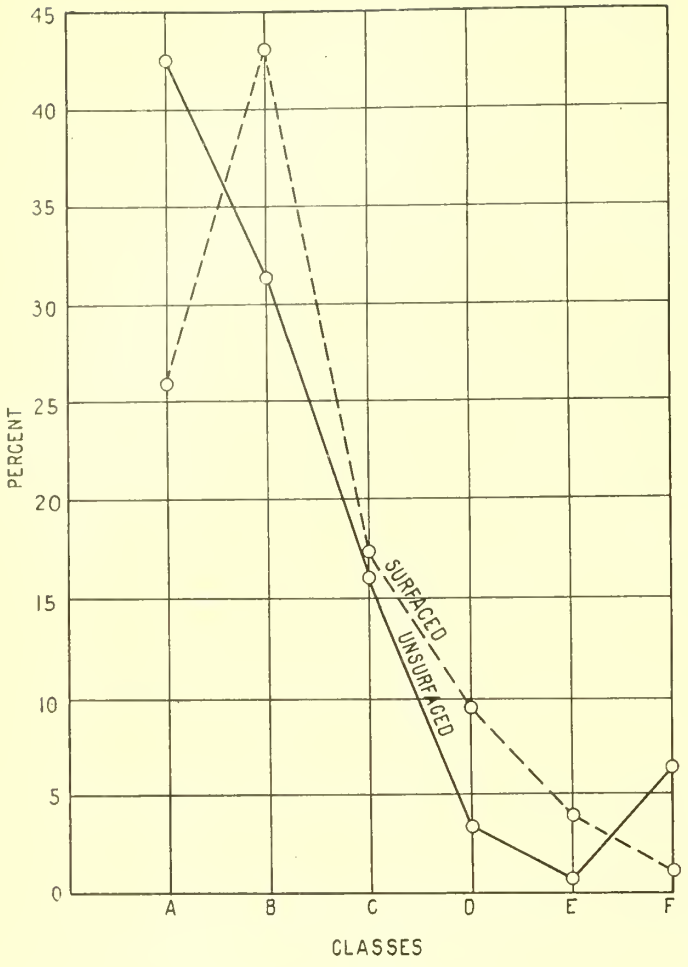
Many miles of the California State highways lie on flat valley floors and have excellent alignment. There are scores of other miles of good location including difficult mountain roads. It is disappointing in the valleys, therefore, to find any location defects such as right-angle section-corner turns and unnecessarily quick reverse curves in passing around railroad station sites and in the mountains and on steeper hills to encounter sharp, blind curves and unnecessary rise and fall. Compensation of grade has not in all cases been sufficient to prevent exceeding the maximum grade if in the future the radii are lengthened.



TRAFFIC DIAGRAM. ROUTE 1, SAN FRANCISCO TO CRESCENT CITY.

It appears that the defects in grade and alignment are due largely to a too strict adherence to a standard. That standard is not invariably economical. A bolder line with considerably increased grading between Eckley and Martinez, for example, would probably not have added much to the first cost and will possibly ultimately have to be built, as this is the main route from San Francisco to Sacramento and is now rather dangerous.

Other locations on hill and mountain roads evidence minimum standards that are too low for trunk lines under present traffic conditions. There are numbers of curves with radii of 50 and 60 feet and grades of 7



PERCENTAGE OF CONCRETE PAVEMENT CLASSES, IN SURFACED AND UNSURFACED PAVEMENT.

per cent that might have been eliminated or reduced at slight additional cost. In a few cases a radical change in line, though doubtless involving added right-of-way costs, would have been a great improvement.

It appears that valuable land has often been avoided and that a location that follows the topography closely has been the rule. These elements have at intervals impaired the alignment and grade.

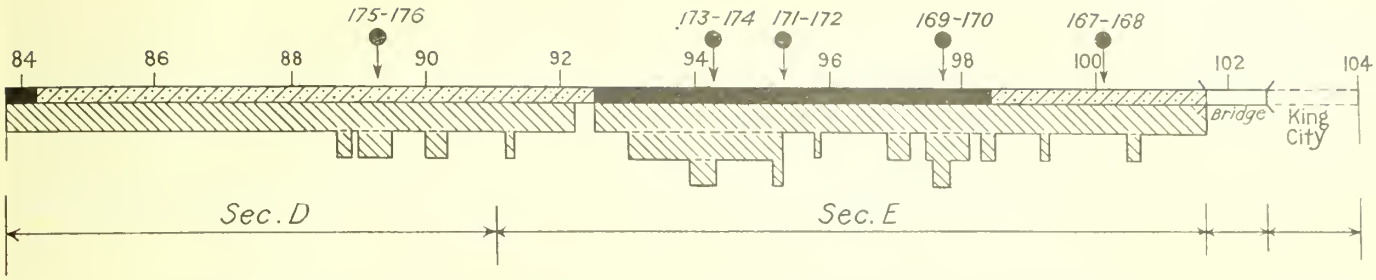
Although the first report of the commission states that travel can proceed at 30 miles per hour over the State highway pavement, it is not safe to travel at that speed at many points, partly because of the narrow pavement and lack of superelevation, but largely because radii are too short. It would appear that where the method of cutting the inside bank to improve sight has been adopted longer radii should have been selected in the first design. In the effort to economize in construction it appears that at times (for example on route 2 between King City and Santa Barbara) too many sharp vertical curves have been used in order to fit the ground.

THE SPECIFICATIONS.

The State highway commission has until recently adhered to the 1912 specifications with few changes. These specifications appear to have been rigidly enforced. The grading has been neatly finished and the subgrade evidently well prepared. The original lean concrete mix of 1 : 2½ : 5 for a pavement should have been abandoned sooner and the permission of 6 per cent of the fine aggregate passing a 100 screen allows a possible excessive clay content. The requirements for coarse aggregate, with respect to size, grading, quality, and cleanliness, are, in the light of recent developments, somewhat inadequate. It is believed the specifications should also exclude the use of alkaline or salt water and permit larger aggregate than 2½ inches. The originally required rough finish has been abandoned, but the finish now obtained can be improved. This rough finish was evidently for a pavement base but it shows through a ⅜-inch top and, where not covered, has doubtlessly tended to increase impact. The old specifications for mixing until texture and color were uniform were evidently unsatisfactory and have been abandoned in favor of a 10-turn or 1-minute mix. The requirements for curing by ponding or wet earth cover are excellent, but some checking due either to lax enforcement of this provision for curing or to a too wet mix has occurred. The omission of transverse joints appears to have been a justifiable innovation, particularly in a frostless country, but it is believed there should be exception to this practice. The present requirement for concrete mixture of 1 : 2 : 4 if laid dry it is believed should produce a good pavement for traffic preponderately rubber tired, but it is remarked that several States use a richer mix. Reinforcement has not been required until 1920, but the present specifications for about 42 pounds of one-half and three-eighths inch steel rods in the center plane per 100 square feet it is believed are excellent. The triangular mesh reinforcement used on Federal-aid project No. 1 was a failure due possibly to improper placement.

With reference to Topeka specifications it is believed that an asphaltic oil of penetration not exceeding 70 should be specified, especially where the temperatures exceed 100° F. and where traffic is also unusually heavy.

With reference to oil macadam, eastern experience indicates that a surface treatment with the largest quantity of oil specified (1¾ gallons) will work into ridges and lumps under traffic. It may be inferred also that with oil paid for by the barrel there will be a corresponding tendency to use the maximum amount. Numerous cases of "viscosity waves" are observable throughout the State.



CLASS CONDITION DIAGRAM. ROUTE 2, MONTEREY COUNTY. THE VARIED HATCHING IN THE UPPER RECTANGLE INDICATES DIFFERENCES IN THE SUBGRADE SOIL; SOLID BLACK REPRESENTS ADOBE AND CLAY AND THE OTHER MARKING SANDY LOAM. THE CLASS OF THE PAVEMENT IS INDICATED BY THE DEPTH OF THE RECTANGLES BELOW, ONE STEP REPRESENTING CLASS A PAVEMENT, TWO STEPS CLASS B, AND THREE STEPS CLASS C, ETC.

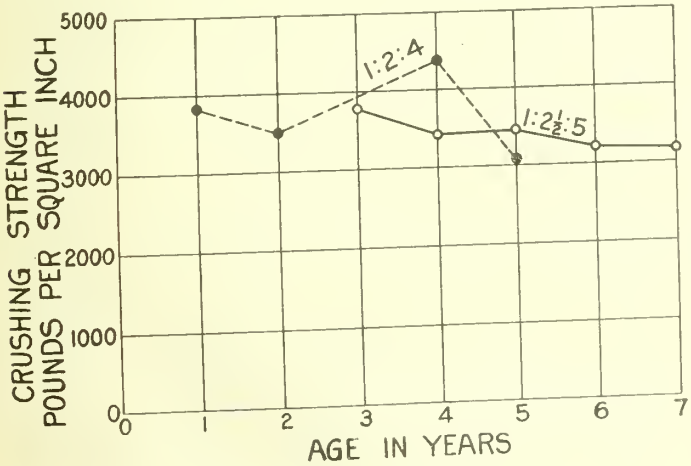
It is remarked that in general the specifications for concrete have, as shown by the tested samples, produced good quality and that they have permitted an economic use of local material with a minimum of failures.

FURTHER DISCUSSION OF POLICY OF EXTENSION OF MILEAGE.

It is necessary in a critical analysis of the standard design to which the State highway commission has adhered for eight years, to make full allowance for the advantage in extension of services made possible by its use. That this concrete construction was begun as a base, however, must not be overemphasized since it was continued for 694 additional miles notwithstanding that supplementary surfacing for financial or other reasons was omitted. The design must be judged as above indicated with reference to the *necessity to extend service and with respect to its continuance under the second bond issue, and in addition with reference to its upkeep and its adaptability to supplementary construction* in those cases where it fails owing to increase in volume or intensity of traffic or other causes.

It is to be remarked that the total motor-vehicle registration in 1920 is about six times that of 1912, and the total truck registration is approximately six times the 1915 figures. The State highway commission has as yet taken no State-wide traffic census.

That the thin, narrow pavement and close grading enabled the rapid extension of very serviceable miles of road is without question, and that the implied order in the legislative act of 1909 demanded extension is equally evident. The voting of the second bond issue in 1915 and the third in 1919 might, in a sense, indicate such a capacity for road financing by the State as to deny the assumption that the State of California, at any time, was obliged to take chances with thin pavement in order to produce mileage, but it is undeniable that the very extension of the pavement developed sufficient sentiment to provide additional money in 1915 and again in 1919. So it can not be said in 1920, in the light of the fact that the great usefulness of the highway system is now proved, that the State would have realized its usefulness and provided funds in equal volume had not the system been extended as rapidly as it was and at some sacrifice of either temporary or ultimate durability to increased mileage.



RELATION BETWEEN AGE OF CONCRETE IN YEARS AND CRUSHING STRENGTH.

There appears, however, to be a serious question, in the light of the fact that 70 per cent of the defective pavement of classes D, E, and F occur on clay and adobe soils, as to the wisdom of a policy which continued the risk of a thin slab on such soils. It is undeniable, however, that a large mileage of the same thin pavement and on adverse soil still remains of classes A, B, and C. We find, however, no conclusive final demonstration of the best construction on the adverse soils, and in that respect failure to vary the design on such soils in the past has postponed the solution of this problem.

The concrete itself is shown by the tests of the sample cores and other samples to be uniformly good; its weight per cubic foot and absorption are practically constant and the amount of coarse aggregate also. The crushing strength averages well above 3,000 pounds to the square inch. There is raised by the diagram of crushing strength by years a question as to whether or not the concrete may be slowly deteriorating, but this condition has not been conclusively proved. More study of this phenomenon is required before any conclusion can be reached. Certainly the slight indicated decrease in strength would not account for any of the adverse conditions found in the pavement.

The question of initial extension versus durability of design is further discussed under the topic of economics with reference to the indicated operating income. There seems grave question, however, as to

the decision in 1917 to continue with the construction of pavement of a low factor of safety. By that time it would seem that the behavior of the design on adverse soils should have been known. Still the change to a mix of 1:2:4 appears to be reflected in the class conditions since only 48 miles of the construction, beginning with 1917, has gone into classes D to F, inclusive, while 109 miles of construction prior to that time are in these classes.

The adaptability of the pavement laid to supplementary construction when it fails is indicated by about 37 miles of this work already done with 30-inch concrete shoulders and 1½-inch Topeka or other bituminous concrete surfacing and with "second-story" concrete. None of this work is sufficiently old to prove its ultimate durability. At present it appears to be carrying traffic with success. The expense of extensive repairing of certain sections prior to such reconstruction has been necessarily heavy. Much of the work so far done has been on roads in such sections that the cross section has not been a serious item, but in many places the roadbed will have to be widened before such supplementary construction of shoulders and surface top can be done.

PRESENT CONDITION OF CONCRETE PAVEMENT.

With reference to the classification adopted for determining the present condition of concrete pavement, it is to be noted that for 4-inch concrete pavement class A is a rather abnormally high type. Pavement of class B, in the light of the present stage of development of concrete roads, appears to be a very normal type of concrete pavement; that is to say, transverse cracks at intervals of approximately 25 feet in a 4-inch pavement without joints may be considered characteristic. Pavement of class C where no separation or faulting follows or accompanies the longitudinal cracks in a 4-inch slab is not unexpected. But where faulting occurs along the longitudinal crack or where there is a distinct separation of the two edges of the crack, an unusual condition is present and the pavement must be regarded as considerably impaired as a structure. Such cases are not infrequent. Pavement of this class C may, however, and usually does, carry traffic without inconvenience. "Crowfoot" cracks at the edge of the pavement in any considerable number are distinct defects; they are not normal and are a characteristic type of defect, and, when followed by settlement or disintegration, impair the service of the road. Pavement of class D in which occurs many areas of concrete of about 50 square feet is decidedly defective, and when accompanied by settlement the service of the road is slightly impaired. Pavement of class E is a failure, and the classification F usually indicates that the concrete itself was bad or that the design of the pavement was inadequate. Travel on this type F is in some instances quite difficult.

The State laid 1,365 miles of concrete and 1,262 miles were classified. Of that classified, 157 miles, or 12.5 per cent, was found in classes D, E, and F, but the degree of impairment is somewhat greater than the percentage, since the defective pavement is distributed throughout the State. The pavement in class F was largely concentrated, and less than 6 miles remain unrestored. The pavement in classes E and D will require reconstruction or heavy repairs and supplementary construction in the immediate future; there are about 114 miles of these two classes.

CONSTRUCTION AND MAINTENANCE.

An analysis of construction and costs shows a rapid building of the important trunk highways to approximate completion and at a very reasonable cost. The total average percentage of construction costs on both day-labor and contract work, chargeable to administration, engineering, and overhead, is 15.86 per cent, and is reasonable. In view of the recent rise in prices, the overrun of 6.24 per cent over the engineer's estimate on final total payment is low. On day-labor jobs this corresponding percentage is higher, as expected, but it is not excessive. Analysis of the 20 jobs, both contract and day-labor, which presented the greatest apparent percentage of overruns shows adequate reasons in practically every instance for such overruns of the estimate.

The accounts in the headquarters office on all work were found very complete and without discrepancies, and the cost figures here presented are accurate and official.

The direct charges for maintenance and improvement are found not to be excessive; the overhead and indirect charges, however, are apparently 19.2 per cent, overhead alone 12.5 per cent, which seems rather excessive. The direct control of maintenance of State highways by the State and the application of the net automobile revenues to this work is believed to be an excellent arrangement. The organization of maintenance under a headquarters maintenance engineer operating through the seven division offices appears adequate, though in some instances rather important job work appears to require more competent direct supervision.

There are at present under maintenance a total of 3,293 miles of State-controlled roads. These include 1,524 miles of earth and gravel roads, including special State roads built prior to 1912, and about 150 miles of oiled county pavement which the State has acquired from the counties. The expenditure for maintenance and improvement of earth and gravel roads is nearly one-third of the entire expenditure.

Since the law now allows the automobile money accruing to the State highway commission to be used for "improvement" it is found that considerable gravel and other surfacing has been done from this fund. The complete analysis or tabulation of distributed maintenance and improvement costs for each original project built, by types and by years, was not attempted, but the data for such analysis, while sometimes confusing, exists in the headquarters records.

Sufficient investigation of the maintenance books was made to determine accurately the unit costs and the summary costs.

It appears that up to 1920 the commission has thought of necessary travel more in direct relation to the increasing maintenance costs rather than in respect to its influence on design of new construction. In this connection it is to be observed that in 1912 the increase of traffic could not be foreseen but it would appear that by the end of 1915 when 1912 registrations had nearly doubled that the 1918 registrations should have been foreseen.

ADMINISTRATIVE AND ENGINEERING ORGANIZATION.

The organization was highly developed. It has continued with little change since 1911. During the war, in common with other State highway departments, it was impaired by loss of personnel and its work hampered by bad industrial conditions. It is not unwieldy and in form is unusually well adapted for the large scale operation it has conducted. The salary scale is good.

The details of the engineering standards are carefully thought out and unusually complete. The standard plans and drawings are excellent, and the clear-cut precision of all engineering operation makes for speed and efficiency. The cost of all overhead and administrative and engineering items on contract jobs has averaged, as mentioned, 15.86 per cent, which in view of the average low cost of construction per mile, is very reasonable, as is similarly 15.88 per cent on day-labor jobs.

There is some evidence of a cramped condition in the functioning of the organization. It appears that headquarters' control is so complete that it may inhibit those reciprocal actions necessary for healthy growth. There is a good opportunity with such an organization to develop this reaction function and initiative of the engineering employees who are in first-hand contact with the job. With the extraordinarily efficient directive functioning in all details, a corresponding return functioning of the organization through the division engineers to headquarters is desirable to develop new ideas with the extension of contact with the job. More initiative and authority would increase efficiency; thus the significance of the adobe reaction might have developed sooner and better alignment could have been produced by changes authorized during construction from reports by resident engineers.

The procedure in advertising and letting of contracts appears to be satisfactory. Some of the early contractors were inexperienced in road work and lost money. This condition has frequently occurred in other States. There is some apparent delay in the completion of final payments due to the routing of the paper.

CONVICT LABOR A SUCCESS.

The State highway department officials report favorably regarding convict work. They bring out these points:

The inaccessible, difficult, inspiring, and remote regions selected proved of advantage as environment and eliminated any criticism of competition with free labor or contact with undesirable "free" citizens.

The kind of work selected—heavy grading and clearing and grubbing—has been well adapted for success.

Unguarded, honor, and long-term convicts work best.

Good camps and food pay, and the outdoor life is wholesome.

There was difficulty at the start, due to dual administrative control by the State prison authority and the State highway commission authority. This conflict was eliminated, and with reward for good behavior and punishment for misbehavior, the work of the convicts has proved economical, especially during the war.

ECONOMIC AND OTHER STUDIES.

The one-day traffic at 103 stations on the State highways is an index of the use of the roads. This traffic day was distributed between August 7 and October 14 and throughout the State, and the assumed daily average total of 2,500,000 vehicle-miles should be representative for the summer interval, or say from June 1 to November 1. The resulting total vehicle-miles of 375,000,000 is 70 per cent on the *State paved highways alone*. There results 262,500,000 vehicle-miles indicated service by such paved highway. The operating income at 5 cents a vehicle-mile is $13,125,000.

To this amount must be added an operating income for the service interval November 1 to June 1. This latter amount can not be based on a traffic figure, but a minimum figure would indicate a total annual operating income of $20,000,000 for 1920.

For preceding years when there were less miles of State pavement and fewer vehicles the operating revenue can not be placed at a greater figure than the corresponding per cent of this total. Thus in 1919 with an average of, say, 450,000 motor vehicles in use, or 90 per cent of the 1920 average, and 93 per cent as much paved highway, there could not have been more than 83 per cent as much corresponding operating income. If the figure is placed at $15,000,000 there results an indicated gross operating revenue in the last two years of $35,000,000.

The element of assumption in the above reasoning is regarded as conservative. It is unnecessary to extend the computation to make immediately evident that the operating income from the State paved highway system alone since 1913 has more than equaled the total expenditure for construction and for repair, improvement, and maintenance of the entire mileage paved and graded by the State. The operating income from the graded portion and the portion built by the counties and acquired and maintained by the State has been disregarded. A corresponding decrease in operating revenue to the community would have occurred had the mileage been shortened by constructing a more durable type.

It is observed that during the decade 1910 to 1920 the estimated value of agricultural products has in-

creased over 300 per cent, the population of the entire State 44 per cent and the *population on the highways*, exclusive of the two largest cities, 63 per cent.

These facts are evidence that the policy of extension of mileage of serviceable pavement was justified in the initial period. Highways, like the railroads, build up business, and a period of supplementary construction follows without financial strain because of increased operating revenues. The advertising value of the highway system has without question added to the population and to the tourist attraction.

STATE CAN NOW AFFORD TO RAISE STANDARD.

Although for the most part the service rendered by the roads built is still uniformly good, it is very evident that the State can now well afford to raise the standard of construction. This standard must satisfy all motor-vehicle operators. The increase in the use of the trucks will doubtless for a time be increasingly rapid. It has been over 500 per cent in seven years and 250 per cent during the past three years and will demand a greatly increased factor of safety in the pavement.

But the increase in motor-registration figures can not be the only index of the future duty of the roads. Additional information useful for the State highway commission can be secured by elaborating the form used for registration, but the necessity of comprehensive traffic census at frequent intervals is great. Only a traffic count will determine the distribution of highway operations and yield corresponding control both of design and maintenance allotments.

The maintenance and repair operation in the past period has involved excessive patching in certain sections due to the thin 4-inch pavement and the increase in traffic volume, weight, and speed. In the future, however, the demand for better quality of pavement service will become more exacting and the increased traffic will require maintenance for various items on any type or standard of pavement, so that as the system develops the aggregate maintenance charge may be expected to increase.

There is evidence that relatively few vehicles have excessive total loads, but field weighings showed a large percentage of overload of trucks per linear inch of solid tire. Unfortunately the exact record of this item was lost. It must be inferred that the infrequent and incidental heavy load is very destructive. Defects of the "crowfoot" type in the pavement are regarded as due solely to traffic impact on the thin slab with adverse subgrade condition. Not only heavy soils but also sandy soils underlie defects of this type, nor is a 4-inch pavement of greater width exempt from such defects. Excessive transverse cracks are also inevitable in a thin slab with any combination of adverse traffic and subgrade conditions.

Whatever design is adopted and whatever the legal speed and loading, there is evidence that increased enforcement of the law is required.

CONCLUSIONS DRAWN FROM THE STUDY.

The State highway system has, in general, been well selected and laid out. The mileage prescribed by law has far exceeded the funds and this discrepancy distorted the policy. The mileage remaining to be built is far in excess of the combined capacity of the third bond issue and all available Federal aid.

The deferred serial type of highway bond adopted is good, but the longest terms of every issue (44–45 years) are very excessive and the long terms will require millions of needless interest. The amounts of money were sufficient to permit planning of comprehensive construction programs and economy of large operations. The legal restrictions on the bonds were seriously embarrassing.[4]

The order of selection and construction of roads from year to year has been largely controlled by necessary policy.

The policy of permitting unpaved exceptions in small incorporated towns is uneconomical and impairs the efficiency of service of the State highways.

The financial administration has been scrupulously honest and careful and the administrative and engineering costs have not been excessive, nor have final costs much exceeded the engineer's estimates.

Convict work has been successful, especially during the war and from both aspects—the road work and reflex effect on the convict. It has been found necessary for success largely to eliminate dual control of convicts on the job. The State prison funds clearly should bear some expense.

There has been a conspicuous growth of motor vehicle registration in California during the past construction period and a corresponding increase in volume and intensity of traffic. The commission evidently did not anticipate this increase and did not provide for it in their original design, nor did they count the traffic throughout the State. A very careful traffic census should be taken at intervals.

It is not believed that modern rubber-tired traffic on a smooth concrete road is abrasive, although solid-tired vehicles doubtless produce some breaking down of edges of separated cracks. No definite correlation was found between total number of vehicles and condition of the concrete pavement itself, but the total traffic does largely determine the wear of shoulders and in many places it does indicate a too narrow width of pavement. It is believed that the impact of excessively heavy loaded trucks, particularly at high speeds, is very destructive to a thin narrow pavement on adverse soils, but it is evident from the data that such trucks are in a small minority in California. Truck traffic is increasing and size and number of commercial passenger busses is very noticeable and there may be expected a parallel increase in the development of commercial freight motor-truck traffic. Passenger busses are already operating on the 15-foot pavement

[4] Such restrictions were removed by the vote of Nov. 2, 1920.

to the disadvantage of other traffic and the law allows a total width of farm load of 10 feet, which is excessive for such pavement.

State authorities can not control the volume nor the distribution of traffic on the State highways, but complete and effective cooperation between the State highway commission and the motor-vehicle department controlling the character of traffic is necessary. The creation of a special State police exclusively to enforce the vehicle laws may be required.

ROADS HAVE PAID FOR THEMSELVES.

There is a very large annual operating revenue to the community from the State highways. The total of this revenue has probably paid for all construction costs to date and would have been correspondingly decreased with less mileage.

A sum equal to the total net motor-vehicle fees at the present average rate will probably always be required for the absolute maintenance and improvement of State highways as construction of the 5,560 miles progresses. The original theory of a license to operate a motor vehicle is obsolete in a community where 97 per cent of traffic is by motor and the registration fee becomes a charge for use of the road. Systematic financing of the upkeep will ultimately adjust the average fee to the requirement of upkeep and also adjust the fee to the vehicle type to more closely indicate the wear produced. An immediate increase of the State's share of the net automobile revenue would be good economy, as a large mileage of defective concrete road must be at once repaired and resurfaced.

The tables and the diagrams of condition and the statistics of sample core and soil tests clearly indicate:

(*a*) A correlation between defective pavements of classes D, E, and F, and adverse soil subgrades; about 110 miles or 70 per cent of 157 miles total of these three classes occur on soils of class 1, which includes all adobe soils.

(*b*) That since the average corrected testing strength of concrete cores is above 3,000 pounds to the square inch the concrete itself is not generally defective in strength nor does it show any wear by traffic.

(*c*) The average class condition of all concrete pavement indicates a slow progressive deterioration with the age of the pavement, and indicates also that the type built tends to reach its approximate stage of classification comparatively soon and thereafter to change more slowly.

(*d*) The diagram showing average strength as determined by cores tested from concrete laid during the various years indicates that there may be a slow progressive deterioration of the concrete itself, or "fatigue" in a thin slab subject to excessive flexure.

(*e*) There is no conclusive indication so far that the previous reinforcement in a 4-inch or 5-inch slab has produced a measurable increase in the quality or durability of the pavement.

(*f*) Diagrams in the report show a slight superiority in the average condition of the concrete pavement surfaced with the three-eighth inch oil top, but in view of obscured classification there is no demonstrated marked superiority of oil surfaced pavement.

(*g*) Typical longitudinal (and other) cracking found on adverse subgrade soils, and shown by many of the 7,500 photographs now on file in the Bureau of Public Roads, indicates a distortion of the subgrade due to varying moisture content and shrinkage. The diagram showing lines of equal moisture content clearly indicates the influence of the concrete pavement in preventing evaporation. The high capillarity of adobe soils and the great shrinkage in the long hot summers thus produce very unfavorable conditions for a thin pavement under increasing traffic.

All pavement of classes D to F, inclusive, which totals 120 miles and much of which is on adobe soils, is doubtless deteriorating and demands immediate repair and supplementary construction. It is doubtful if much of the pavement of these classes, especially on adobe, will ultimately prove an adequate base for a 1½-inch Topeka top. An adequate "second-story" concrete if extended to a total width of 20 feet to thus include two new concrete shoulders of full depth is to be preferred.

STRONGER PAVEMENTS DEMANDED.

There are sufficient typical failures to show that in the future only designs of increased strength and adapted to resist such failure should be used. Every possible precaution will be necessary to prevent failure on adverse subsoils of adobe, clay-adobe, or similar soils. On such soils, in the absence of any proved successful design, only short sections of tentative design should be attempted, or there should be first developed frank experimental construction to determine a workable and economical design.

Such a design will require the reinforcement now provided by the commission, a more massive type of concrete not less than 6 inches in average depth, some adequate corrective treatment of subgrade and possibly a form of "mulching" of shoulders to prevent evaporation. A flat subgrade is desirable and less crown.

It is believed that on the main roads more satisfactory results will follow a considerably bolder standard of location on hill and mountain grades and that an increase in width of pavement to a minimum of 18 feet is now desirable, with more systematic widening and superelevation on curves.

Under modern traffic conditions there is an increasing demand for unimpaired alignment and fast travel between centers. To this end designs of highways must produce in general a road that can be traversed at a speed of 30 miles per hour throughout and without excessive operating costs due to changing speeds, etc. Therefore, first economy in grading becomes of rapidly decreasing advantage and must give way to the increased safety and comfort of travel.

There would be advantage in some exceptions to the present standard of no transverse joints. In the hot valleys considerable buckling of the 4-inch slab occurs with attendant disintegration in infrequent instances. This tendency to buckle would doubtless be reduced by

a thicker slab. Experiments with transverse joints at varying intervals is desirable on adverse or adobe soils. The future pavement will require a much larger factor of safety.

The policy of construction of grading and drainage structures and gravel surface only on certain roads in districts 1, 2, and 3 in particular, was economically sound and deferring of paving up to the present doubtless justified. Through roads with a minimum of unimproved gaps and with adequate standard for most interstate travel have resulted from this policy.

A high standard of design and workmanship is displayed by the structures and the costs have been very reasonable. Many bridges exhibit attractive designs of unusual elegance. In many places the side-hill type of inlets is not functioning. The prevailing type of guardrail is a reflection of the original purpose to protect horse-drawn traffic and might be modified to advantage in maintenance cost. Railroad grade-crossing elimination, where undertaken, has been well done and will require constantly more attention and investment of State funds.

The standard of finish on concrete pavement has improved, but it is believed that still greater refinements will constantly be demanded and will probably pay in reduction of impact and resulting injury to, and by traffic. It is not believed that the continued use of the three-eighths-inch oil top is justified by past experience; the concrete should be laid not as a base but a wearing surface.

There is nothing presented by the entire California study that indicates that concrete is not a successful pavement. One of the clearest results is the emphasis on the need of better subgrade protection. Highway grading is more exacting than railroad grading.

There should be further studies in respect to—

(*a*) Traffic, with a new traffic census before June 1, 1921, and periodically thereafter.

(*b*) The indicated slow deterioration of the existing concrete, with continuing core tests.

(*c*) Soils, including a considerable elaboration of the moisture-content study in pavement protected subgrades, a determination of the thickness of necessary protective soils layers on adobe and of the required percentage of admixture to lessen shrinkage and increase the bearing power, and a further study of capillarity and critical moisture content.

(*d*) Alkali and its effect when present in the subgrade or in the mixing or ponding water.

It is believed that the motor-vehicle registration law should provide separate records of the numbers of (*a*) all commercial trucks, including rubber-tired trucks, (*b*) all public freight trucks of certain important classes, (*c*) all foreign cars, and (*d*) all public passenger-carrying busses and should contain strict provisions regarding tire conditions on all solid-tired trucks with respect to the minimum rubber cushions and flat tires, or projections, etc.

The work of the State highway commission and the highway engineer shows a continuous and intelligent devotion to public duty. Their construction operations have been widely extended under greatly varying conditions. A high degree of standardization was doubtless necessary and is evident. The failures (12.5 per cent of D, E, and F pavement) are not extensive and some were inevitable on large scale work. The 4-inch, 15-foot concrete pavement was continued beyond the point of success on adverse soils and more time will be needed to develop a type of construction certain of success on such soils. The operations have produced a large mileage of very serviceable road and from an economic standpoint are conspicuously successful and of continuing benefit to the State. The operating income from the highways is now sufficiently large to insure the economic success of a considerably increased standard of production.

OH, FOR A SIGN AT THE TURN OF THE ROAD.

"Where is the road to Tumbleday?"
I asked a farmer making hay.
"Just keep straight on, that 'airs the way,
You cain't git off the road, I'll say."

So we drove on a mile or more
And then let out a swearful roar;
For there the road was split in two
And we knew not the thing to do.

No sign was there to indicate!
The way to go was left to fate,
And she was mean; we took the right,
And lost a day and half a night.

That road was hard and smooth and fine,
For forty rods—or forty-nine.
Beyond, great bumps were on its spine;
Its health had entered a decline.

It narrowed down, by stone walls bound,
So autos could not turn around.
And ne'er a thing for us to see
But worse and worse variety.

Rocks, stumps, and gullies on it lay
Till goats could scarcely climb that way.
And sand and mud were there so deep,
Our engine quit and went to sleep.

Footsore and mad we found the end
Of that bum road around a bend.
And there we saw (with feelings hard)
It petered out in farmer's yard.

We also learned we should have took
That other road which we'd forsook!
It cost much time, and fifteen bones,
To get hauled back through mud and stones.

And now I plead for just one sign
Where forked roads do intertwine,
Or where they cross, or come and go,
To points the stranger can not know.

And how I wish there lived so keen
A man who had within his bean
A notion clear to give to you
Of how to get beyond his view.

—*George E. Ladd.*

9,231,941 MOTOR CARS AND TRUCKS REGISTERED BY THE STATES IN 1920

By ANDREW P. ANDERSON, Highway Engineer, Bureau of Pubic Roads.

A TOTAL of 9,231,941 motor cars, including commercial vehicles, were registered in 1920 in the 48 States and the District of Columbia. There were also registered a total of 239,102 motor cycles. The registration and license fees including those for chauffeurs, operators, and dealers, amounted to a total of $102,546,212.25.

As compared with 1919, the data for 1920 represent an increase of 22 per cent, or 1,666,495 motor cars. This increase alone lacks only about 4 per cent of being equal to the total registrations of the United States for the calendar year 1914. In this connection it is interesting to note that the number of motor cars registered in 1920 in the State of New York exceeded the total cars registered in the United States in 1910. Furthermore, the revenues derived from the registrations in the State of New York in 1920 were about equal to the entire registration revenues of the United States for the year 1913. The revenues derived from all registrations and licenses during the year 1920 exceed those of 1919 by 59 per cent or a total of $37,848,596.67, which increase is practically equal to the total registration revenues of the United States for the calendar year 1917.

GREAT INCREASE IN REVENUES.

The increase in the motor-car registrations and revenues in the United States during the past 14 years presents many interesting comparisons. This is especially true in respect to the use made of the revenues. In 1906 the total registrations were approximately 48,000 cars, paying a gross revenue of about $193,000, or about the same as that collected by the State of Arizona during the year 1920. In 1906 the gross registration revenues were equivalent to less than three-tenths of 1 per cent of the total rural road and bridge expenditures for that year, while the registration revenues for 1920 are equal to about one-fourth of the total rural road and bridge expenditures for the calendar year 1919. Furthermore, while in 1906 practically none of the motor-vehicle revenues was applied to road maintenance or construction, 95 per cent, or a total of $97,671,742.10, was used for this purpose in 1920, and of the total amount applied to road work, 79 per cent, or $77,527,518.29, was expended under the control or supervision of the several State highway departments. The remaining 5 per cent not applied to road work was expended very largely for number plates and in carrying out the provisions of the motor-vehicle registration laws in the several States.

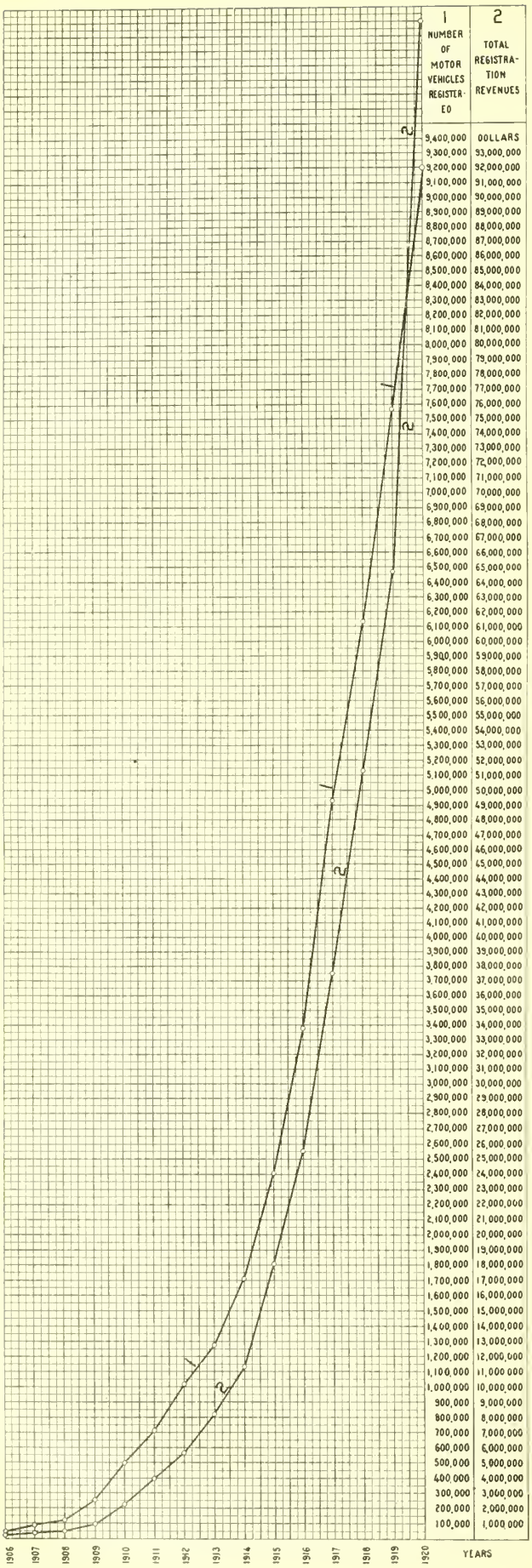
On January 1, 1921, every State but Minnesota had made provision for some definite form of annual State registration. In Minnesota a three-year registration period ended on December 31, 1920. The registration figures for Minnesota, therefore, are the total number of cars registered during the period of three years. How many of these cars have been removed from the State or have been scrapped there is no way of determining. A few States make as yet no distinction between original registrations and reregistrations or transfers. Consequently in these States the number of registrations is in excess of the actual number of cars. In most States, however, the registration figures represent fairly accurately the actual number of cars in the State during the year.

MORE MONEY GOES TO ROAD WORK.

For a number of years the general tendency toward devoting an ever-increasing portion of the net motor vehicle revenues to road work under the control and direct supervision of the State highway departments has been very noticeable. Prior to 1912 only a very small portion of the motor vehicle revenues was devoted to road work under the State highway departments. In 1920, however, 76 per cent of the total motor vehicle revenues, or $77,527,518.29 was applied to road work under the direct supervision of the State departments, and $20,144,223.81 additional was applied to road work by counties or other local subdivisions but with little or no direct supervision from the State highway departments.

In most States the motor-vehicle revenues are devoted to maintenance and repair of the State roads or other improved highways. These States thus seem to have solved fairly well the difficult problem of securing funds for the maintenance of the more important roads under the ever-increasing traffic requirements. As both the traffic and the revenues increase with the number of cars, there seems to exist a possibility of so adjusting the registration rates as to keep pace with the ever-growing maintenance changes.

A number of States having in general but a small mileage of improved roads have recently adopted the plan of capitalizing the motor-vehicle revenues and devoting these funds to road construction. These States are Illinois, Maine, Minnesota, Missouri, Nevada, Utah, and Wyoming. In these States bonds have been voted or issued for road construction, and the principal and in some cases also the interest is to be paid entirely from the motor-vehicle revenues. There seems to be no doubt that these revenues may be made sufficient for this purpose. The question as yet to be solved by these States is: From what other source can sufficient maintenance revenues be secured so as to prevent the deterioration of the roads constructed from the bond issues?



HIGHER TAXES FOR HEAVY MOTOR TRUCKS.

At the beginning of 1921 there were still seven States in which motor trucks were registered at the same rate as passenger cars. The past five or six years, however, have shown a very decided tendency toward increasing the fees required for heavy motor trucks over and above those required for passenger cars. This increase is usually based on the weight of the truck, its carrying capacity, its horsepower, or a combination of these factors. The most general practice seems to incline toward definitely limiting the maximum total loaded weight of the vehicle and basing the registration fee on the carrying capacity of the truck. Some few States have adopted a scale of fees which in actual practice serves to make the operation of very heavy trucks unprofitable. A number of States have also provided legislation to limit the maximum wheel load per inch of tire.

It is unfortunate that the term motor truck and commercial vehicle is as yet rather indefinitely defined in the laws of a number of the States. In a few States no distinction is made between passenger cars and freight-carrying vehicles, while in one State only trucks used for hire are classed as commercial vehicles.

SIX STATES TAX GASOLINE.

The States of Colorado, Kentucky, New Mexico, North Carolina, Oregon, and Washington in addition to the registration fees, also levy a State tax on gasoline or other products used for the propulsion of motor vehicles. In Alabama, Delaware, Idaho, Iowa, Michigan, New Hampshire, New York, North Dakota, Oklahoma, Oregon, South Carolina, Pennsylvania, Tennessee, and Vermont the registration fees are in lieu of all personal property taxes. In other States, however, motor cars are taxed as personal property in addition to the required registration fees. In comparing the registration rates in the several States this fact should be borne in mind.

The registration of automobiles, motor trucks, commercial vehicles, chauffeurs and operators, dealers and manufacturers, as well as the total gross revenues and the amount available for State road work, either by the State highway departments or under their supervision, and that available for local road work for the year 1920 are given in Table 1. The number of registrations in this table does not necessarily indicate the exact number of motor vehicles in use or existence in the several States except in so far as the laws of the several States require and enforce an annual registration under these classifications. All of the States with the exception of Minnesota now require an annual registration. Some States, however, do not segregate registrations from reregistrations, consequently the registration figures in these States exceed the actual number of cars by the number of transfers which have been made during the year. It

is unfortunate that, during 1920, only 36 States required motor trucks and commercial vehicles to be registered in separate classes. Consequently the data in column 3 in Table 1 do not give a very definite index as to the total number of trucks in existence except in those States requiring separate registration. Even where separate registration is required the classification as to what constitutes a motor truck is far from uniform. Consequently, in some cases, a vehicle which is classed as a truck or commercial vehicle in one State may, in another, be included among passenger or motor cars for registration purposes. Reference to the principal requirements for the registration of motor vehicles are given in Table 4 and these will serve to make clear what the data in Table 1 actually represent.

Table 2 gives a compilation of the total registrations and total revenues for the years 1915 to 1920, inclusive. For further information in regard to registrations and revenues previous to 1913 the reader is referred to Public Roads Bulletin No. 48, Repair and Maintenance of Highways, pages 68 to 71, inclusive, and also to the files of Public Roads for the years 1919 and 1920.

TABLE 1.—Motor-Vehicle Registrations and Revenues, 1920.

State.	Automobiles.	Motor trucks and commercial vehicles.	Motor cycles.	Reregistrations or transfers.	Owners' and chauffeurs' licenses.	Manufacturers' and dealers' licenses.	Total gross motor-vehicle registration and license revenues.	Motor-vehicle revenues available for road work.		Average gross revenue return per motor-car registration.	Population per motor car.	Motor cars per mile of public rural road.
								By or under State highway department.	Under direction of local authorities.			
Alabama	61,941	12,696	1,035	1,200	3,413	1,411	$835,178.00	$668,142.40	.....	$11.23	31	1.3
Arizona	29,868	4,733	542	1,816	417	251	192,368.92	189,868.92	.....	5.55	10	2.9
Arkansas	59,082	[1]	[2]	333	478	548	591,464.50	550,000.00	.....	10.01	30	1.2
California	541,934	41,689	20,564	126,827	865,699	3,524	5,714,717.40	2,441,601.45	$2,441,601.45	9.79	5	9.5
Colorado	121,506	7,749	3,420	11,509	131,449	2,822	819,872.74	375,699.01	375,699.01	6.34	7	3.2
Connecticut	95,123	24,011	[3] 6,543	20,156	139,843	814	1,852,591.00	1,852,591.00	.....	15.55	12	8.5
Delaware	18,300	[1]	674	[1]	22,023	606	329,980.00	329,980.00	.....	18.03	12	5.0
District of Columbia	[4] 29,131	[5] 5,030	2,648	1,189	17,767	927	266,285.00	.....	.....	7.78	13	.....
Florida	63,466	10,448	1,275	1,544	2,190	719	554,695.14	554,695.14	.....	7.63	13	4.1
Georgia	134,000	12,000	1,382	2,894	5,055	976	1,919,338.92	1,851,540.82	.....	13.14	20	1.8
Idaho	50,861	[1]	764	851	802	581	882,034.51	220,508.65	661,525.86	17.34	8	2.0
Illinois	504,250	64,674	10,369	[1]	566,701	6,239	5,915,700.17	[6] 5,915,700.17	.....	10.40	11	5.9
Indiana	300,226	32,841	8,823	[1]	9,758	1,500	2,029,694.00	1,902,363.00	.....	6.09	9	4.5
Iowa	407,578	29,800	4,000	90,000	3,870	2,575	7,507,202.08	[7] 7,244,450.00	.....	17.16	5	4.2
Kansas	294,159	[1]	3,605	12,598	.....	2,411	1,419,345.50	.....	1,327,308.00	4.83	6	2.6
Kentucky	99,437	13,246	1,543	[1]	5,000	1,016	815,549.31	815,549.31	.....	7.24	21	1.9
Louisiana	66,000	7,000	512	602	.....	515	390,000.00	.....	350,000.00	5.34	25	3.0
Maine	55,395	7,512	1,566	[1]	78,539	637	818,755.50	[6] 818,755.50	.....	13.02	12	2.7
Maryland	[8] 87,625	[9] 15,216	5,222	9,960	54,269	4,368	2,124,924.84	1,537,540.00	384,385.00	20.53	14	6.2
Massachusetts	223,112	51,386	15,143	30,000	361,546	2,011	3,860,231.70	3,500,000.00	.....	14.07	14	14.7
Michigan	366,946	45,771	8,011	35,640	195,477	1,638	5,754,900.96	2,745,715.10	2,737,138.35	13.94	9	5.6
Minnesota [10]	[10] 324,166	[1]	7,546	5,716	8,920	641	143,794.50	143,794.50	.....	.44	7	3.5
Mississippi	63,721	4,765	194	834	63,267	260	[11] 800,000.00	[11] 750,000.00	.....	11.68	26	1.5
Missouri	297,008	[1]	3,954	16,400	323,799	2,520	2,111,696.85	2,111,696.85	.....	7.11	11	3.1
Montana	59,450	1,200	675	862	1,490	429	416,245.00	280,557.37	93,519.12	6.86	9	1.5
Nebraska	200,000	19,000	2,100	[1]	.....	3,000	[11] 2,800,000.00	[11] 2,100,000.00	[11] 700,000.00	12.78	6	2.7
Nevada	10,464	[1]	125	[1]	.....	75	103,318.33	[6] 103,318.33	.....	9.87	7	.9
New Hampshire	[12] 30,240	4,440	2,542	4,475	43,993	252	654,702.04	580,342.23	.....	18.69	13	2.5
New Jersey	204,125	23,612	11,041	41,351	294,438	2,671	3,503,936.76	3,441,770.32	.....	15.39	14	15.3
New Mexico	22,100	[1]	219	[1]	.....	175	200,000.00	180,000.00	.....	9.05	16	.6
New York	524,271	[16] 151,934	30,092	[1]	358,022	3,560	8,863,250.59	6,721,174.52	2,142,076.07	10.14	15	8.3
North Carolina [11]	127,405	13,455	1,418	.....	.....	.....	1,785,000.00	1,785,000.00	.....	10.26	18	2.7
North Dakota	90,840	[1]	898	10,150	.....	.....	691,500.00	274,257.70	274,257.69	7.61	7	1.3
Ohio	[13] 538,090	83,300	23,300	[1]	.....	24,244	[11] 6,400,000.00	[11] 3,100,000.00	[11] 3,100,000.00	10.30	9	7.2
Oklahoma	204,300	8,580	1,360	[1]	.....	1,202	[11] 2,500,000.00	[7] 2,294,404.67	.....	11.74	10	2.0
Oregon	103,790	[1]	3,434	16,568	142,962	751	2,085,168.50	1,469,145.28	489,715.10	20.09	7	2.8
Pennsylvania	521,835	48,329	23,981	57,712	261,183	13,154	8,090,873.04	8,090,873.04	.....	14.01	15	6.2
Rhode Island	40,914	9,563	2,260	5,790	58,710	231	531,462.75	468,162.75	.....	10.51	12	23.3
South Carolina	93,843	[1]	908	1,933	.....	1,541	527,868.13	92,529.19	329,765.31	5.63	18	2.2
South Dakota	112,589	7,806	777	2,545	.....	1,071	[11] 784,000.00	.....	[11] 700,000.00	6.51	5	1.2
Tennessee	90,214	11,638	1,151	5,754	.....	564	1,215,776.04	571,816.72	571,816.72	11.94	23	2.2
Texas	427,693	[1]	4,290	121,280	23,385	3,624	3,510,355.97	1,468,474.63	1,715,116.13	8.21	11	3.3
Utah	37,060	5,556	1,114	[1]	1,120	235	350,933.29	[6] 325,000.00	.....	8.23	11	4.8
Vermont	28,709	2,916	946	3,290	39,201	192	555,422.38	515,736.76	.....	14.40	11	2.2
Virginia	101,800	13,670	2,233	[1]	5,514	2,972	1,822,736.16	1,730,921.18	.....	15.70	20	2.1
Washington	[14] 144,131	29,789	4,915	13,337	.....	3,977	2,828,896.10	[11] 1,800,000.00	[11] 1,000,000.00	16.15	8	4.1
West Virginia	69,862	10,802	1,659	[1]	10,552	886	1,280,193.28	1,096,662.43	.....	15.87	18	2.5
Wisconsin	277,093	16,205	8,002	[1]	.....	1,946	3,127,073.00	2,250,000.00	750,000.00	10.67	9	3.8
Wyoming	23,926	[1]	327	[1]	.....	201	267,179.35	[4] 267,179.35	.....	11.16	8	1.6
Total and average	8,379,579	852,362	239,102	718,116	4,100,852	106,473	102,546,212.25	77,527,518.29	20,144,223.81	11.11	11	3.8

[1] Included under automobiles.
[2] Registration not required.
[3] Includes 2,178 side cars.
[4] Does not include 14,797 nonresident cars.
[5] Does not include 1,790 nonresident trucks.
[6] To pay interest and provide sinking fund for State highway bond issue; remainder for State highway work.
[7] Distributed to counties, but expended under supervision of State highway department; 2½ per cent of grand total to State highway department for expenses.
[8] Does not include 13,500 nonresident registrations.
[9] Includes 4,022 buses and vehicles used for hire.
[10] Registrations cover a period of three years ending Dec. 31, 1920. Number of cars given are for total period; revenues are for calendar year only.
[11] Approximate.
[12] Does not include 2,359 nonresident and neutral zone cars.
[13] Does not include 2,683 State, county, and city cars.
[14] Does not include 1,287 exempt cars.
[15] Data covered period of 18 months ending Dec. 31, 1920.
[16] Includes 26,533 omnibuses.

TABLE 2.—Motor-Vehicle Registrations and Gross Motor-Vehicle Revenues, 1915 to 1920.

	Motor-car registration.[1]						Total gross revenues.					
	1915	1916	1917	1918	1919	1920	1915	1916	1917	1918	1919	1920
Alabama	11,634	21,636	32,873	46,171	58,898	74,637	$180,744	$203,655	$217,700	$470,274	$541,348.70	$835,178.00
Arizona	7,753	12,300	19,890	23,905	29,575	34,601	45,579	73,000	117,643	142,288	164,755.68	192,368.92
Arkansas	8,021	15,000	28,693	41,458	49,450	59,082	80,551	150,000	205,176	410,649	500,970.00	591,464.50
California	163,797	232,440	306,916	407,761	477,450	583,623	2,027,432	2,192,699	2,846,030	3,524,036	4,468,721.67	5,714,717.40
Colorado	28,894	43,296	87,460	83,244	104,865	129,255	120,801	197,795	296,808	379,559	490,432.31	819,872.74
Connecticut	41,121	56,048	74,645	86,067	102,410	119,134	536,970	768,728	1,080,757	1,285,164	1,516,136.01	1,852,591.00
Delaware	5,052	7,102	10,700	12,955	16,152	18,300	55,596	85,249	133,883	232,449	286,333.00	329,980.00
District of Columbia	8,009	13,118	15,493	30,490	35,400	34,161	29,396	47,624	55,928	220,753	274,184.00	266,285.00
Florida	[2] 10,850	20,718	[3] 27,000	54,186	55,400	73,914	[3] 60,000	127,176	[3] 170,000	345,775	401,317.40	554,695.14
Georgia	25,000	46,025	70,324	101,676	137,000	146,000	125,000	154,735	229,653	331,816	429,848.00	1,919,338.92
Idaho	7,071	12,999	24,731	32,289	42,220	50,861	121,259	213,758	412,641	576,555	729,702.94	882,034.51
Illinois	180,832	248,429	340,292	389,620	478,438	568,924	924,906	1,236,566	1,588,835	2,764,330	3,262,714.00	5,915,700.17
Indiana	96,915	139,065	192,194	227,160	227,255	333,067	587,318	817,285	1,096,159	1,293,128	1,558,740.50	2,029,694.00
Iowa	145,109	198,587	254,462	278,313	364,043	437,378	1,533,054	1,776,170	2,249,655	2,547,596	3,077,445.81	7,507,202.08
Kansas	72,520	112,122	159,343	189,163	228,600	294,159	387,588	585,762	830,878	978,837	1,150,000.00	1,419,345.50
Kentucky	19,500	31,500	47,420	65,884	90,008	112,683	117,117	184,741	287,314	402,250	565,520.21	815,549.31
Louisiana	11,380	17,000	28,394	40,000	51,000	73,000	75,600	112,000	166,835	240,000	306,000.00	390,000.00
Maine	21,545	30,972	41,499	44,572	53,425	62,907	268,412	363,562	491,693	570,171	685,570.25	818,755.50
Maryland	31,047	44,245	60,943	74,666	95,634	102,841	386,565	565,302	807,395	1,189,984	1,776,410.22	2,121,924.84
Massachusetts	102,633	136,809	174,274	193,497	247,182	274,498	1,235,724	1,602,958	1,969,994	2,184,821	2,667,853.85	3,860,231.70
Michigan	114,845	160,052	247,006	262,125	325,813	412,717	373,833	1,739,344	2,471,271	2,875,266	3,719,433.39	5,754,900.96
Minnesota	93,269	[4] 46,000	[5] 54,009	204,158	259,741	324,166	[3] 160,540	82,469	100,000	1,076,811	218,469.50	143,794.50
Mississippi [3]	9,669	25,000	36,600	48,400	59,000	68,486	76,700	175,000	250,000	335,000	400,000.00	800,000.00
Missouri	76,462	103,587	147,528	188,040	244,363	297,008	323,289	439,315	617,942	1,394,762	1,725,076.70	416,245,00
Montana	14,540	25,105	42,749	51,053	59,324	60,650	33,120	52,768	290,936	350,914	407,848.00	2,111,696.85
Nebraska	59,000	101,200	148,101	173,374	200,000	219,000	[3] 183,000	311,334	451,303	536,897	304,450.55	2,800,000.00
Nevada	2,009	4,919	7,160	8,159	9,305	10,464	7,875	20,116	31,166	31,083	37,550.75	103,318.33
New Hampshire	13,449	17,508	22,267	24,817	31,625	34,680	257,776	344,434	425,305	509,335	599,621.25	654,702.04
New Jersey	81,848	109,414	141,918	155,519	190,873	227,737	1,062,923	1,406,806	1,923,164	2,431,757	2,931,904.15	3,503,936.76
New Mexico	5,100	8,228	14,086	17,647	18,082	22,100	29,625	47,865	80,843	105,631	111,150.00	200,000.00
New York	255,242	314,222	406,016	459,292	566,511	676,205	1,991,181	2,658,042	4,284,144	4,945,298	5,984,659.50	8,863,250.59
North Carolina	21,000	33,904	55,950	72,313	109,017	140,860	123,000	206,101	321,923	394,739	1,313,950.73	1,785,000.00
North Dakota	24,908	40,446	62,993	71,678	82,885	90,840	79,245	125,283	211,536	471,429	636,842.40	691,500.00
Ohio	181,332	252,431	346,772	412,775	511,031	621,390	984,622	1,286,405	1,766,427	2,125,426	2,593,000.00	6,400,000.00
Oklahoma	25,032	52,718	100,199	121,500	144,500	212,880	154,892	555,011	853,659	1,102,380	1,178,130.27	2,500,000.00
Oregon	23,585	33,917	48,632	63,324	83,332	103,790	108,881	146,232	196,787	461,422	602,239.00	2,085,168.50
Pennsylvania	160,137	230,578	325,153	394,186	482,117	570,164	1,665,276	2,325,057	3,268,025	4,048,186	5,090,921.00	9,080,873.04
Rhode Island	16,362	21,406	37,046	35,218	44,833	50,477	206,440	264,737	346,117	385,608	477,223.25	531,462.75
South Carolina [2]	15,000	[6] 25,000	38,332	55,492	70,143	93,843	15,000	10,000	113,557	300,217	389,034.68	527,868.13
South Dakota	28,724	44,271	67,158	90,521	104,628	120,395	[3] 180,000	140,746	210,592	282,742	322,340.50	784,000.00
Tennessee	[7] 7,618	[3] 30,000	48,000	63,000	80,422	101,852	[3] 34,000	186,953	322,200	390,000	585,181.95	1,215,776.04
Texas [2]	40,000	[6] 125,000	192,961	251,118	331,310	427,693	20,000	20,000	858,978	2,039,589	2,624,334.29	3,510,355.97
Utah	9,177	13,507	24,076	32,273	35,236	42,616	[3] 60,000	93,494	170,707	229,203	291,325.96	350,933.29
Vermont	11,499	15,671	21,633	22,553	26,807	31,625	218,480	297,992	363,541	398,856	460,190.87	555,422.38
Virginia	21,357	35,426	55,661	72,228	94,100	115,470	176,875	271,266	518,566	684,636	900,000.00	1,822,736.16
Washington	38,823	60,734	91,337	117,278	148,775	173,920	238,717	350,052	519,526	875,391	2,325,323.53	2,828,896.10
West Virginia	13,279	20,571	31,300	38,750	50,203	80,664	128,952	198,436	359,339	447,705	1,008,083.31	1,280,193.28
Wisconsin	79,741	115,645	158,637	196,253	236,290	293,298	431,977	615,721	861,278	2,076,701	2,502,852.00	3,127,073.00
Wyoming	3,976	7,125	12,523	16,200	21,371	23,926	19,880	35,625	57,421	80,000	102,114.50	267,179.35
Total	2,445,664	3,512,996	4,983,340	6,146,617	7,565,446	9,231,941	18,245,711	25,865,370	37,501,233	51,477,417	64,697,255.58	102,546,212.25

[1] Does not include motor cycles nor dealers' and manufacturers' licenses.
[2] State registrations only.
[3] Estimated.
[4] Cars registered during 1916; total number of cars, approximately 138,000.
[5] Cars registered, 1917.
[6] Estimated number of cars in State.
[7] Registrations 1915 only.

TABLE 3.—Motor Vehicle Registration and License Fees in Force January 1, 1921.

State.	Motor cycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
Alabama	$5; with sidecar attachment, $7.50.	Less than 25 horsepower, $11.25; 25 to 29 horsepower, $18.75; 30 to 39 horsepower, $26.25; 40 horsepower and over, $30; electric cars, $20.[1]	Less than 1 ton, $15; 1 to 2 tons, $22.50; 2 to 3 tons, $37.50; 3 to 4 tons, $56.25; over 4 tons, $75.	Original, $5; renewal, $2.50.	None	$25 to $125.
Arizona	$2	25 horsepower and under, $5; 26 to 40 horsepower, $10; over 40 horsepower, $15.	Same as passenger cars	Perpetual, $5.	do	1 vehicle of each class at passenger-car rates.
Arkansas	None	All motor vehicles, $10	do	$1	do	Do.
California	$2	Electric cars, $5; all others, 40 cents per horsepower; trailers, $2.	Equipped with pneumatic tires, same as passenger cars; others pay additional; less than 2 tons unloaded, $5; 2 to 3 tons, $10; 3 to 5 tons, $15; over 5 tons, $20.	Original, $2; renewal, $1.	No fee	Regular rates for each set of plates.
Colorado	Same rate as passenger cars.	One-half of 1 per cent of cost price; minimum fee, $5.	1 ton, $10; 2 tons, $17.50; 3 tons, $25; 4 tons, $37.50; 5 tons, $50, and $25 per ton for each additional ton, carrying capacity.	$2	None	$20; additional tags, $2.50 per set.
Connecticut	$2	50 cents per horsepower	½ ton or less, $11; 1 ton, $15, and increasing to $200 for 8 tons, and $100 per ton for each ton additional.	License, $2; examination, $2.	License, $2; examination, $2.	$50 for 5 pair of plates, additional plates, $10 per pair.[2]
Delaware	$5	$2 each 500 pounds gross weight of car and load; passengers figured at 125 pounds each.	Same as passenger cars	$3	$3; family, $8.	$20 for 2 pairs of tags; extra tags, $10 per pair.

[1] Cars used for transportation of passengers paying fare, 5 or less passenger capacity, $37.50; 6 to 9 passenger capacity, $40; 10 or more passenger capacity, $90; operating between towns or cities 10 miles or more apart, a flat fee of $60.
[2] In case of manufacturers, $25, plus $1 for each car tested on public roads.

TABLE 3.—Motor Vehicle Registration and License Fees in Force January 1, 1921—Continued.

State.	Motor cycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
District of Columbia.	$2	24 horsepower or less, $3; 25 to 30 horsepower, $5; over 30 horsepower, $10.	Same as passenger cars	$2	$2	Regular rates for each car demonstrated on public roads.
Florida [3]	$2	22 horsepower or less, $5; 23 to 27 horsepower, $8; 28 to 35 horsepower, $12; above 35 horsepower, $15 any car seating more than 9 persons, $100.	1 ton or less, $10; 1 to 2 tons, $25; 2 to 4 tons, $50; more than 4 tons, $100. Trailers over 500 pounds capacity same rate as trucks.	$2	None	5 cars, $15.
Georgia	$5	Not exceeding 23 horsepower, $11.25; over 23 horsepower 60 cents per horsepower.	Not exceeding 1 ton capacity, $15; others, $15 plus $7.50 for each ½ ton over 1 ton; 4 tons, $75; 5 tons, $150; 6 tons, $375; 7 tons, $1,125.	$2	do	$50 for 5 number plates.
Idaho	$5	All weighing less than 2,001 pounds, $15; 2,001 to 3,000 pounds, $20; 3,001 to 4,000 pounds, $30; over 4,000 pounds, $40.	Same as passenger cars	$2	do	$35 for one make and $25 each additional make.
Illinois [4]	$4	25 horsepower or less, $8; 26 to 35 horsepower, $12; 36 to 50 horsepower, $20; over 50 horsepower, $25; electric cars, $12.	Total loaded weight, 5,000 pounds or less, $12; 5,000 to 12,000 pounds, $22.50; 12,000 to 15,000 pounds, $35; over 15,000 pounds, $60.	Original, $5; renewal, $3.	do	$12 for 2 plates and $12 for each pair duplicates.
Indiana	$2	Electric cars, $5; others, 25 horsepower or less, $5; 26 to 40 horsepower, $8; 41 to 50 horsepower, $15; over 50 horsepower, $20.	Less than ¾ ton, $6; 1 ton, $8; 1 to 2 tons, $10; 2 to 3½ tons, $20; 3½ to 5 tons, $30; 5 to 7½ tons, $40; over 7½ tons, $50.	$2	do	$25; duplicate plates, $1 each.
Iowa	$5	One per cent of values of car plus 40 cents per 100 pounds of weight of vehicle. Minimum fee, $10.	With pneumatic tires—1-ton capacity or less, $15; 1½ tons, $22.50; 2 tons, $30; 2½ tons, $45; 3 tons, $65; 3½ tons, $90; 4 tons, $105; 4½ tons, $120; 5 tons, $135; 6 tons, $165. With solid rubber tires—less than 2-ton capacity, same as above, 2½ tons, $55; 3 tons, $75; 3½ tons, $100; 4 tons, $115; 4½ tons, $130; 5 tons, $145; 6 tons, $175; trailers, $10 to $70.	$2	None	$25
Kansas	$2	All cars, $5 each	Same as passenger cars	None	do	$15 for 3 sets of tags; extra tags, 50 cents each.
Kentucky	$10	60 cents per horsepower	½ ton or less, $22; 1 ton, $30; and increasing to $150 for 5 tons, and $50 per ton for each ton additional.	$2	do	$25 for one set of plates; additional plates, $1 per set.
Louisiana	$2	25 cents per horsepower, with a minimum fee of $5 per car.	All motor trucks, $7.50 each	None	do	1 regular registration for each make; secondhand dealers, $10
Maine	$3	15 horsepower or less, $5; 16 to 35 horsepower, $10; over 35 horsepower, $15.	$10 per ton capacity for cars to 5-ton capacity, then $15 per ton for each ton above 5-ton capacity.	$2	$2	$25 for 5 pairs of plates; extra plates, 75 cents each.
Maryland	$5; with side car, $8.	60 cents per horsepower; minimum charge, $10; $1.20 per horsepower if operated for hire.	With solid tires to 3-ton capacity, $20 per ton; 4-ton, $100; 5-ton, $150; 6-ton, $300; 7-ton, $500; electrics, one-half of above rates; trailers to 1-ton capacity, $10; others, $20 per ton.	$3	$2	$25 for 2 sets of tags and $12 for each additional set. For dealers in motor cycles, 4 tags, $20; additional tags, $5 each.
Massachusetts	$5	Under 30 horsepower, $10; 30 to 39 horsepower, $15; 40 to 49 horsepower, $20; 50 horsepower and over, $25.	$10 for each ton capacity or fraction thereof; trucks with pneumatic tires, one-half above rates.	$2; examination, $2.	$2; examination, $2.	$25 for 5 cars, and $5 additional for each car over 5 operated on public roads.
Michigan	[5]	Electric cars, $1 for each motor horsepower plus 35 cents for each 100 pounds of weight; others, 25 cents per horsepower plus 35 cents for each 100 pounds of weight.	Same rates as passenger cars. Trailers, 50 cents for each 100 pounds of weight.	$2	$0.50	$30 for 3 cars and $10 for each additional car.[6]
Minnesota	$2	All cars, $2 for year 1920	Same as passenger cars	Original, $1.50; renewal, $1.	None	$20; extra plates, $1 per set.
Mississippi	$12	Electric cars, $15; others, $2 plus 50 cents per horsepower.	1-ton capacity or less, $12; 1½ tons, $17; 2 tons, $32; 3 tons, $57; 4 tons, $117; 5 tons, $202; 6 tons, $252; over 6 tons, $75 per ton.	None	do	Regular rates for 4 sets of plates.
Missouri	[5]	Less than 12 horsepower, $4; 12 to 23 horsepower, $6; 24 to 35 horsepower, $10; 36 to 47 horsepower, $14; 48 to 59 horsepower, $16; 60 to 71 horsepower, $20; 72 power and over, $24.	Same as passenger cars	$1.50	do	$10; for each duplicate, $5.
Montana	$5	23 horsepower or less, $5; 24 to 50 horsepower, $10; over 50 horsepower, $15.	1-ton capacity or less, $5; over 1 ton and less than 2, $15; over 2 tons and less than 3, $25; over 3 tons, $40.	$2	do	Cars, $50; motor cycles, $15.
Nebraska	$5	$10, plus 50 cents for each 100 pounds car weighs over 2,000 pounds.	$10, plus 50 cents for each 100 pounds total weight of loaded car exceeds 2,000 pounds.	None	do	Registration for each class.
Nevada	[5]	35 cents for each 100 pounds of total weight of loaded car.	Same as passenger cars	do	do	$20 for 4 number plates; $1 for each duplicate.
New Hampshire	$2	15 horsepower or less, $10; 16 to 30 horsepower, $15; 31 to 40 horsepower, $20; 41 to 50 horsepower, $25; 51 to 60 horsepower, $30; over 60 horsepower, $40.	do	Original, $5; renewal, $1.	Original, $3; renewal, $1.	$50 for 6 pair of plates; additional plates, $5 per pair.

[3] Any county or municipality may charge an additional license tax, not to exceed 50 per cent of State license tax, on motor vehicles used for hire.
[4] Both cars and trucks may be registered in municipality in which owner resides.
[5] Same rate as passenger cars.
[6] In case of manufacturers, motor cycles $20, including 10 number plates.

TABLE 3.—Motor Vehicle Registration and License Fees in Force January 1, 1921—Continued.

State.	Motor cycles.	Passenger cars.	Motor trucks and commercial cars.	Chauffeurs.	Owner operators.	Dealers and manufacturers.
New Jersey	$2	10 horsepower or less, $4.50; 11 to 29 horsepower, $7.50; 30 horsepower or over, $15.	With solid tires loaded weight ½ ton or less, $6, and $3 additional for each ½ ton gross weight to 2 tons; then $4 for each additional ton; trailers, $3.	$3	$3	$5 per car not to exceed 5.
New Mexico	$3	40 cents per horsepower	50 cents per horsepower	None	None	$25; additional tags, $5 each.
New York	$2.50	25 cents per horsepower plus 40 cents per $100 of list price.	Gross loaded weight 2 tons or less, $10, and $5 each additional ton to 14; 14 tons, $70, and $10 each additional ton.	Original, $5; renewal, $2.	Original, $2; renewal, $1.	$15, plus $5 for each duplicate set.
North Carolina	$5	26 horsepower or less, $10; 26 to 30 horsepower, $15; over 30 horsepower, $20.	1-ton capacity or less, $12.50; 1 to 2 tons, $25; 2 to 3 tons, $40; 3 to 4 tons, $65; 4 to 5½ tons, $100. Trailers, 1-ton capacity, $10, plus $20 for each additional ton.	None	None	$25, plus $5 for each duplicate pair of plates.
North Dakota	$3	10 cents per horsepower, plus 5 mills per dollar of selling price and 20 cents per 100 pounds net weight of car. Minimum fee, $5. Electric cars, $2.	Same as passenger cars, plus following fee for capacity rating: To 3 tons, $3 per ton; to 4 tons, $5 per ton; over 4 tons, $10 per ton. Trailers, one-fourth truck fee.	do	do	Dealer pays regular fee and transfers tags to purchaser.
Ohio	$2.50; side cars, $1.50.	25 horsepower or less, $8; 25 to 35 horsepower, $12; over 35 horsepower, $20; electrics, $8.	Same as passenger cars, plus 20 cents for each 100 pounds of total loaded weight.	$3	do	$20; extra plates, $2 per pair.
Oklahoma	$10	$10 per car if list price is $500 or less; if list price exceeds $500, then 75 cents additional for each $100 of list price.	1,500 pounds capacity or less $15; 2,000 pounds, $20; 3,000 pounds, $25; 4,000 pounds, $40; 6,000 pounds, $60; 8,000 pounds, $100; over 8,000 pounds capacity, $300.	None	do	$25 for 2 tags and $12.50 each for additional set of tags.
Oregon	$6	Electric cars, $18; others, 23 horsepower and less, $15; 23 to 26 horsepower, $22; 26 to 30 horsepower, $28; 30 to 36 horsepower, $36; 36 to 40 horsepower, $48; over 40 horsepower, $56.	Electric trucks, $30; others, 1½ to 2 tons, $32, and $12 for each additional ½ ton up to 5 tons; over 5 tons allowed only on special permits.	$4	25 cents	$30 for 2 tags and $5 for duplicate sets.
Pennsylvania	$3	40 cents per horsepower; minimum fee, $10.	Less than 1 ton weight same as passenger cars; others, 1 to 1¼ tons, $20; 1½ to 2¼ tons, $25; 2½ to 3 tons, $30; 3 to 3½ tons, $50; 1½ to 4 tons, $75; 4 to 5 tons, $100; over 5 tons, $150. With metal tires double above rates. Trailers, $2 to $15.	$2	No fee	Regular rates for each set of plates.
Rhode Island	$2	15 horsepower or less, $5; 16 to 30 horsepower, $10; 31 to 40 horsepower, $15, over 40 horsepower, $25.	Carrying capacity 1 ton or less, $7, with $3 additional for each ton to 4 tons, and then $4 for each ton above 4 tons; over 9-ton capacity, $40 each; trailers, $10 to $30 each.	$1	$1	$25 for 5 vehicles and $5 for each additional vehicle.
South Carolina	$3	Cars weighing 2,000 pounds or less, $6; others $2 additional for each 500 pounds over 2,000.	Capacity 1 ton or less, $15; 2 tons, $30; 3 tons, $60, 4 tons, $100; 5 tons, $200; 6 tons, $250, 7 tons and over, $350.	None	None	$25 for first make and $15 for each additional make.
South Dakota	$3	All cars $6 each	Capacity 2 tons or less, $6; 2 to 3½ tons, $10; 3½ to 5 tons, $15.	do	do	$25 for 6 plates, duplicates $3 each.
Tennessee	(5)	50 cents per horsepower	50 cents per horsepower, plus $5 per ton carrying capacity.	do	do	$25.
Texas	$3	35 cents per horsepower	Capacity 1 ton or less, same as passenger cars; others, 1 to 2 tons, $16; 2 to 3 tons, $32; 3 to 4 tons, $48, 4 to 5 tons, $80; above 5 tons, $100 for additional ½ ton. County license also required.	$3	do	$15; extra numbers, $5 each.
Utah	$3	Electric cars, $10; others, 25 horsepower and less, $5; 26 to 40 horsepower, $10; above 40 horsepower, $15.	Total loaded weight 1 ton or less, $10; 1 to 2 tons, $15; over 2 tons, $7.50 per ton. With pneumatic tires two-thirds and with metal tires double above rates.	$2	do	$25, and $2 for each set of duplicate plates.
Vermont	(5)	First registration, $1 per horsepower; second, 75 cents per horsepower; third registration and thereafter, 50 cents per horsepower.	Less than 3-ton capacity, $20 per ton; 3 tons and over $25 per ton.	$3; examination, $2.	$2	$50.
Virginia	60 cents per horsepower; minimum, $5.	60 cents per horsepower; minimum fee, $10.	$15 for first ton capacity, plus $5 for each ½ ton additional capacity. Trailers, $10 first ton capacity, plus $3 for each ½ ton additional.	$5	None	$50 for 3 sets of plates; additional sets, $15 each.
Washington	$6	$10, plus 60 cents for each 100 pounds car weighs over 1,500 pounds.	$10, plus 40 cents for each 100 pounds that total loaded weight exceeds 1,500 pounds unless empty truck weight exceeds 6,500 pounds, then 50 cents per 100 pounds. Trailers same rates.	None	do	Cars, $50; extra plates, $10 per pair; motor cycles, $10.
West Virginia	$5	Cars weighing 1 ton or less, $10, and 25 cents additional for each 100 pounds over 1 ton.	Same as passenger cars. Special rates for trucks used for hire.	$3	do	Cars, $15 per set of plates; motor cycles, $5.
Wisconsin	$4	All cars $10 each	Capacity less than 2,100 pounds, $15; 2,100 to 5,100 pounds, $20; 5,100 pounds or more, $25.	(7)	do	$25 for 4 plates; extra plates, $1 each.
Wyoming	$5	40 cents per horsepower	75 cents for each 100 pounds of weight of vehicle.	None	do	$50 for 1 plate; $2 for each additional plate.

[5] Same rate as passenger cars.

[7] Drivers of cars operating for hire may be licensed by municipality.

TABLE 4.—Administrative Provisions in Force Jan. 1, 1921, Affecting Motor-Vehicle Registrations, Licenses, and Revenues.

State.	Registration and licenses.					Revenues from registrations and licenses.			Revenues from fines and penalties applied to roads.	Traffic regulations made by—
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Nonresidents' exemption.	Applied to—	Proportion expended for roads under supervision of—			
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
Alahama	State tax commission through probate judge.	Annual, Oct. 1.	Chauffeur, annual, Oct. 1.	Chauffour, must be 18 years old.	Reciprocity.	80 per cent to state highway fund.	All of net	None	None	Statute.
Arizona	Secretary of state	Annual, Jan. 1.	Chauffeur, perpetual.	No examination.	6 months.	State road tax fund.	All of net	do	do	Statute and local ordinance.
Arkansas	Commissioner of State lands, highways and improvements.	do	Chauffeur, annual from date.	Chauffeur, must be 18 years old.	Reciprocity.	State and county road work.	One-half	One-half.	One-half of penalty for delinquency.	Do.
California	Superintendent of motor-vehicle department.	do	Chauffeur, annual, Jan. 1.	do	3 months.	State and county road work.	One-half net.	One-half net.	All, by local community.	Do.
Colorado	Secretary of state	do	do	Certificate as to competency.	90 days	State and county road work.	do	do	Same as registration revenues.	Do.
Connecticut	Commissioner of motor vehicles.	do	All operators, annual, Mar. 1.	Examination	30 days	Maintenance state roads.	All of net	None	do	Do.
Delaware	Secretary of state	do	All operators, Jan. 1.	Must be 16 years old; no examination.	Reciprocity.	State highway department.	All	do	None	Do.
District of Columbia.	Automobile board	do	All operators, perpetual.	Examination	do	General fund	None	do	do	
Florida	State comptroller	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	30 days	State highway department and state, maintenance fund.	All of net	do	do	Do.
Georgia	Secretary of state	Annual, Mar. 1.	Chauffeur, annual, Mar. 1.	Must be 16	30 days	Net to state aid road fund.	do	do	do	Do.
Idaho	Secretary of state through county assessor.	Annual, Jan. 1.	Chauffeur, annual.	Chauffeur, must be 18 years of age.	Reciprocity.	State highway fund.	25 per cent	75 per cent	Same as registration revenues.	Do.
Illinois	Secretary of state	do	Chauffeur, annual, Jan. 1.	Chauffeur, examination.	60 days	State road fund.	All [1]	None	All, by local community.	Do.
Indiana	do	do	do	do	do	State highway fund.	All of net	do	County road fund.	Do.
Iowa	do	do	do	Chauffeur must be 18 years of age and competent.	Reciprocity.	State road work.	[2]	do	Local road work.	Do.
Kansas	Secretary of state through county treasurer.	Annual, July 1.	do	Must be 14 years of age.	60 days	Net, maintenance county and township roads.	None	All of net	None	Statute and city ordinance.
Kentucky	State tax commission through county clerk.	Annual, Jan. 1.	do	Chauffeur, must be competent.	Reciprocity.	Net to state road fund.	All of net	None	do	Statute and local ordinance.
Louisiana	Secretary of state	do	None	[3]	do	Net to parish road work.	None	All of net	Same as registration revenues.	Local ordinance.
Maine	do	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination optional.	30 days	State road work.	All [1]	None	None	Statute and local ordinance.
Maryland	Commissioner of motor vehicles.	do	Owner, perpetual; chauffeur, annual.	do	Reciprocity; 3 months.	Net 20 per cent Baltimore street work; 80 per cent state road maintenance.	80 per cent of net.	do	Same as registration revenues.	Do.
Massachusetts	Department of public works.	do	All operators, annual from date.	Examination all operators.	Reciprocity.	Net 20 per cent small town roads; 80 per cent maintenance state roads.	All net	do	do	Statute, department of public works and local ordinance.
Michigan	Secretary of state	do	Chauffeur, annual, Jan. 1.	Examination optional.	Reciprocity to 90 days.	State and county road work.	One-half net.	One-half net.	None.	Statute and local ordinance.
Minnesota	do	Triennial, 1918–1920.	do	Chauffeur, examination.	30 days	Net, state road and bridge fund.	All net	None	do	Do.
Mississippi	State auditor and county tax collector.	Annual, Jan. 1.	None	None	30 days	Net to state highway fund.	do	do	Net, same as county revenue.	Local ordinance.
Missouri	Secretary of state	Annual, Feb. 1.	Chauffeur, annual, Feb. 1.	Must be 18 years of age; no examination.	60 days	State road fund.	All of net	do	None	Statutes and local ordinance.
Montana	do	Annual, Jan. 1.	Chauffeur, annual, Jan. 1.	No examination.	No limit	Net to state and county road work.	Three-fourths net.	One-fourth net.	do	Do.
Nebraska	Department of public works through county treasurer.	do	None	Must be 16 years old.	30 days	do	Three-fourths.	One-fourth	do	Statute, department of public works and local ordinance.
Nevada	Secretary of state	First Monday in February	do	do	do	Net to state highway bond fund.	None	None	do	Do.

[1] Must first set aside amount necessary to finance state highway bonds.
[2] 94 per cent for construction of primary roads, 2½ per cent for maintenance of highway department, and 5 per cent for registration expenses.
[3] Municipalities of more than 10,000 population may license chauffeurs.

TABLE 4.—Administrative Provisions in Force Jan. 1, 1921, Affecting Motor-Vehicle Registrations, Licenses, and Revenues—Continued.

State.	Registration and licenses.					Revenues from registrations and licenses.			Revenues from fines and penalties applied to roads.	Traffic regulations made by—
	Official or department in charge.	Renewals.		Requirements for operators' and chauffeurs' licenses.	Non-residents' exemption.	Applied to—	Proportion expended for roads under supervision of—			
		Car registrations.	Operators' and chauffeurs' licenses.				State highway department.	Local road authorities.		
New Hampshire.	Commissioner of motor vehicles.	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination, all operators.	20 days....	Road maintenance.	All of net..	None.....	Same as registration revenues.	Statute, departmedt of public works and local ordinance.
New Jersey..	.....do.....	...do.....	.....do.....	.....do.....	Reciprocity; 15 days.	.....do.....	...do.....	...do.....	.....do.....	Statute and motor vehicle commission.
New Mexico..	Secretary of state ...	Annual, Jan. 1.	None.....	Must be 14 years old.	30 days....	Net State and county road work.	All of net..	...do.....	None.....	Statute and local ordinance.
New York...	.....do.....	Annual, Feb. 1.	All operators, annual, Feb. 1.	Chauffeur, examination.	Reciprocity.	State and local road work.[4]	75 per cent gross.	25 per cent gross.	Maintenance of State roads.	Statute, State highway commission, and local ordinance.
North Carolina.	.....do.....	Annual, July 1.	None.....	Must be 16 years of age.	Reciprocity to 60 days.	State road fund..	All net....	None.....	None.....	Statute and local ordinance.
North Dakota.	Motor vehicle registration department.	Annual, Jan. 1.	.....do.....	.....	No limit..	Net to State and county road work.	One-half..	One-half..	.....do.....	Do.
Ohio.....	Secretary of state ...	...do.....	.....do.....	.....	...do.....	State and local road maintenance.	...do.....	...do.....	.....do.....	Statute, State highway department, and local ordinance.
Oklahoma....	Department of highways.	...do.....	.....do.....	.....	Reciprocity; 60 days.	10 per cent appropriated for State highway department; 90 per cent county road work.	All.....	.....	All.....	Statute and local ordinance.
Oregon.....	Secretary of state.....	...do.....	Chauffeur, annual, Jan. 1.	Must be 16 years of age; no examination.	Reciprocity.	Net to State and county road work.	Three-fourths.	One-fourth	County road fund.	Do.
Pennsylvania	State highway department.	...do.....	.....do.....	Affidavits as to competency.	...do.....	Maintenance of State highways.	All gross..	None.....	State and local road work.	Statute, State highway department, and local ordinance.
Rhode Island	State board of public roads.	...do.....	All operators, annual from date.	Examination, all operators.	Reciprocity; 10 days.	Maintenance State roads.	All net....	...do.....	Same as registration revenues.	State board of public roads statute, and local ordinance.
South Carolina.	State highway department.	...do	.....	.....	30 days....	Maintenance highway department and county road work.	...do.....	...do.....	None.....	Statute an local ordinance.
South Dakota	Secretary of state through county treasurer.	...do.....	.....	Must be 15 years old.	Reciprocity.	90 per cent county road work.	None.....	90 per cent	.....do.....	Do.
Tennessee....	State department of highways through county clerk.	...do	.....	.....	30 days....	Net to State and county road work.	All net....	.....	Same as registration revenues.	Do.
Texas.....	State highway department through county tax collector.	...do.....	Chauffeur, annual, Jan. 1.	Must be 18 years of age.	90 days...[4]	Net to State and county highway funds.	50 per cent	50 per cent	County road work.	Do.
Utah.....	Secretary of state ...	Annual, Mar. 1.	.....do.....	No examination.	30 days....	Motor vehicle registration fund.	All net [5]...	None.....	None.....	Do.
Vermont.....	.....do.....	Annual, Jan. 1.	All operators, annual, Jan. 1.	Examination, chauffeur.	Reciprocity.	State maintenance fund.	...do.....	...do.....	.....do.....	Do.
Virginia.....	Secretary of commonwealth.	...do.....	Chauffeur, annual, Jan. 1.	Certificate of competency.	2 periods of 7 days each.	Net to construction and maintenance of State roads.	...do.....	...do.....	.....do.....	Do.
Washington..	Secretary of state through county auditor.	Annual, Mar. 1.	None.....	Operators must be 15 years of age, chauffeurs 21.	90 days....	Net for maintenance and construction.	50 per cent[6]	50 per cent[6]	Same as registration revenues.	Do.
West Virginia	State road commission.	Annual, Jan. 1.	Chauffeur, annual, Jan. 1.	Must be 14 years of age.	Reciprocity.	State road fund..	All.....	None.....	None.....	Statute, State road commission, and local ordinance.
Wisconsin....	Secretary of state.....	...do.....	None.....	Must be 16 years of age.[7]	...do.....	Net to State highway fund and county road work.	75 per cent net.	25 per cent net.	.....do.....	Statute and local ordinance.
Wyoming....	.....do.....	...do.....	.....do.....	Must be 15 years of age.[1]	Reciprocity to 90 days.	All to State roads.[5]	All [5].....	None.....	.....do.....	Statute.

[1] Must first set aside amount necessary to finance State highway bonds.
[4] Does not apply to revenue collected within New York City, one-half of which goes to the city general fund.
[5] To pay interest and sinking fund on State road bonds.
[6] Approximate, exact division made by legislature when funds are appropriated.
[7] Drivers of cars operating for hire may be licensed by municipalities.

RESURFACE CONCRETE ROAD WITH REINFORCED CONCRETE

By T. M. KEENE, District Engineer, Bureau of Public Roads

THE resurfacing of a worn-out concrete pavement with a thin concrete slab instead of the usual topping of bituminous material is perhaps sufficiently unusual to render of interest a brief rehearsal of the main features of this type of construction.

This type of resurfacing has been proposed and approved for Idaho Federal aid project No. 49, which comprises 1.54 miles of the Idaho-Pacific highway on the outskirts of Boise, Idaho. This section of roadway was paved in 1912 with one course of 6-inch concrete, rather poorly laid, which under the heavy traffic imposed upon it has gone to pieces in many places, and so many cracks and potholes have developed that some method of reconstruction has become imperative.

Traffic on this section amounts to about 2,800 vehicles daily, of which 250 are motor trucks. The old pavement was laid 16 feet wide, and in view of the heavy traffic above noted, this width has become manifestly inadequate, and any improvement must involve the widening of the pavement to a standard double-track width of 18 feet.

BIDS FAVORED CONCRETE SLAB.

Since the original intention was to retop this pavement with a bituminous mix, bids were asked for on a top of this type as well as on a conctete slab, but resulting prices were so greatly in favor of the latter construction that in spite of its comparative novelty its use was recommended and approved. Bids were respectively $2.10 per square yard for a 2-inch bituminous concrete top, and $1.30 per square yard for a 3-inch cement concrete slab.

Construction of the concrete slab topping will involve, first, the placing of an extra strip of concrete 1 foot in width on each side and to the full depth of the old pavement. These strips will consist of a 1:2:4 mix, struck off even with the old surface. At the same time the old slab itself will be cleaned and all depressions filled with the same mix and struck off so that a base slab 18 feet wide with a uniform surface shall be obtained. The new concrete is to be thoroughly cured before placing the top slab.

While the use of a bituminous top requires as close a bond as possible between the top and the concrete base, a topping of cement concrete calls for a method which will result in an entire absence of bond between the top and base. The extent of contraction and expansion in the two courses would vary considerably and bonding the two together would doubtless increase the tendency to crack, whereas a complete separation of the two slabs will permit of a slight movement in each slab independent of the other. Therefore, after the new portions of the reconstructed base are sufficiently hardened the surface is to be thoroughly cleaned and sprinkled with a light uniform coating of hot Tarvia. There will then be placed on the Tarvia-coated base a layer of concrete of a 1:2:3 mix 1½ inches in depth. On this layer is to be placed a reinforcing fabric consisting of a flat steel wire mesh weighing not less than 28 pounds per 100 square feet, and additional concrete is to be immediately deposited to secure a completed thickness of 3 inches.

Since the old pavement had expansion joints at 30-foot intervals, similar joints are to be placed in the concrete topping at the same points, although it is planned to break joints in a few instances as an experiment to determine the comparative value of such spacing for future work.

METHOD DESERVES CONSIDERATION.

The adoption of a concrete slab topping might be inadvisable in places where grades are fixed within very narrow limits, as, for instance, on curbed streets; also, on account of the length of time that the road must be closed to traffic, this construction might be objectionable where no suitable detours are available. In general, however, it would appear that this method should be given careful consideration as affording a competitive type of resurfacing for concrete roads, which, even if not adopted, would tend to reduce bids on other types with consequent ultimate economy.

The experience of the board of county commissioners of Wayne County, Mich., has been of value in forming recommendations in regard to this somewhat unusual method of resurfacing, and thanks are expressed for their courtesy in furnishing details of their methods and the results of their experience.

MERCHANTS' ASSOCIATION CONDEMNS OVERLOADING AND SPEEDING MOTOR TRUCKS.

The Merchants' Association of New York, by unanimous action of its board of directors, at a meeting held March 10 adopted a resolution strongly condemning the practice, now altogether too prevalent, of overloading and speeding motor trucks, with resulting injury of the highways.

After stating that the practice results in serious damage to roads and in many cases their complete destruction, and that the result of such operation is creating in the public mind an unfriendly attitude, the resolution calls for a more rigid enforcement of existing laws and the enactment of adequate laws where such practices are not now specifically prohibited. This resolution is signed by the special committee on highway development, of which Lee J. Eastman is chairman.

FEDERAL AID ALLOWANCES.

PROJECT STATEMENTS APPROVED IN FEBRUARY, 1921.

State.	Project No.	County.	Length in miles.	Type of construction.	Project statement approved.	Estimated cost.	Federal aid.
Arkansas	37	Washington	[2] 3.230	Gravel	Feb. 12	[2] $3,402.74	[2] $9,000.00
	51	Conway	[2] 2.330	Macadam	...do...	[2] 35,604.45	[2] 15,000.00
	78	Lincoln	[2] 2.090	Gravel	Feb. 18	[2] 20,242.64	[2] 10,000.00
	79	Conway	[2] 2.240	Macadam	Feb. 15	[2] 14,611.78	[2] 25,000.00
	92	Grant	[2] 4.310	Gravel	Feb. 19	[2] 19,639.95	[2] 10,000.00
	101	Polk	38.050	.....do	Feb. 7	132,153.72	55,036.07
	115	Madison	[3] 5.350	.....do	Feb. 23	[3] 16,950.78	.....
	118	Drew and Chicot	7.110	.....do	Feb. 26	177,695.87	82,797.00
Colorado	94	El Paso and Fremont	3.068	Sand-clay	Feb. 12	37,016.32	18,508.16
	102	Ouray	1.051	Earth	Feb. 8	45,942.93	21,020.00
	172	Gunnison	3.201	Gravel	Feb. 26	49,268.56	24,634.28
	178	Rio Grande	.....	Bridge	...do...	44,000.00	22,000.00
	182	Eagle	3.257	Earth	Feb. 21	119,152.00	59,576.00
Georgia	73	Richmond	.....	Bridge	Feb. 8	[1] 12,584.00	[1] 6,292.00
	127	.....do	.....	.....do	Feb. 21	129,530.06	1,000.00
	137	Bibb	[1] 4.000	Concrete	Feb. 9	[1] 141,940.99	[1] 55,000.00
	206	Tattnall	3.220	Sand-clay	Feb. 23	38,745.42	19,372.71
	214	Bartow	1.000	.....do	Feb. 26	21,848.75	10,924.37
	218	Polk	1.000	Chert	Feb. 15	31,268.60	15,634.30
Indiana	28	Vanderburg and Gibson	10.000	Brick, concrete, or bituminous concrete.	...do...	415,662.50	207,831.25
Louisiana	17	Tangipahoa	4.910	Sand-clay and gravel	Feb. 24	[1] 65,541.08	32,770.54
	18	Caldwell	[1] 2.400	.....do	Feb. 21	[1] 11,462.99	5,000.00
	27	Rapides	11.810	Sand-clay, washed gravel	Feb. 19	[3] 157,388.35	[3] 78,694.17
	29	Franklin	[1] 10.470	Sand-clay, gravel	Feb. 24	[1] 100,496.81	[1] 50,000.00
	43	Calcasieu	[1] 11.790	Gravel and shell	Feb. 27	[1] 245,092.59	[1] 122,546.29
	68	Gaddo	9.500	Macadam base	Feb. 24	[1] 371,447.73	[1] 185,723.86
	73	Richland	[3] 20.190	Sand-clay, gravel	Feb. 25	[3] 430,605.56	[3] 171,221.78
Michigan	53	Ogemaw and Arenac	20.000	Gravel	Feb. 8	353,409.32	176,704.66
	54	Shiawassee and Genesee	16.500	Concrete or bituminous concrete	Feb. 19	767,734.00	330,000.00
	59	Van Buren	5.231	Concrete	Feb. 12	212,267.17	104,620.00
Minnesota	30	Wright	[2] 21.860	Earth	Feb. 21	[3] 17,454.09	.....
	119	Faribault	27.250	.....do	Feb. 16	202,216.08	52,000.00
	189	St. Louis	1.530	Gravel	Feb. 14	26,823.50	13,000.00
	201	.....do	1.030	Brick, concrete, or asphalt	Feb. 19	63,985.68	20,000.00
Mississippi	45	Yalobusha	21.000	Earth	Feb. 8	132,715.00	66,357.50
	95	Pike	6.400	Brick	Feb. 26	203,568.20	101,784.10
	99	Tallahatchie	13.100	Earth	Feb. 12	200,607.00	100,000.00
	110	Lauderdale	5.100	Gravel	Feb. 8	36,567.85	18,283.92
Missouri	147	Monroe	7.500	.....do	Feb. 28	66,374.00	33,187.00
	179	Stoddard	8.500	.....do	...do...	88,200.00	44,100.00
	180	Buchanan	6.500	Concrete	Feb. 8	351,532.00	130,000.00
	181	Osage	.....	Bridge	Feb. 12	48,000.00	24,000.00
Montana	139	Ravalli	7.000	Gravel	Feb. 19	79,677.51	39,838.75
Nebraska	168	Holt and Rock	21.700	Earth	Feb. 7	102,135.00	51,067.50
New Hampshire	133	Grafton	0.400	Gravel	Feb. 28	9,000.00	4,500.00
New Jersey	29	Atlantic	[1] 9.356	Concrete	Feb. 2	[1] 492,250.00	[1] 187,120.00
North Dakota	96	Ramsey	[4] 2.500	Earth	Feb. 16	[2] 23,300.00	[2] 1,650.00
	110	Grand Forks	5.100	Gravel	Feb. 21	63,982.05	31,991.02
	117	.....do	10.000	Earth	...do...	46,200.00	23,100.00
	119	Emmons	4.500	.....do	...do...	20,790.00	10,395.00
	120	Towner	11.500	.....do	Feb. 18	66,792.00	33,396.00
	121	Nelson	11.000	.....do	Feb. 16	50,820.00	25,410.00
	123	Logan	14.000	.....do	Feb. 18	64,680.00	32,340.00
	124	Barnes	14.500	.....do	...do...	65,714.00	32,857.00
	125	Grand Forks	11.000	Gravel	Feb. 24	147,620.00	73,810.00
	126	Barnes	10.000	Earth	...do...	50,820.00	25,410.00
	127	Burke	7.500	.....do	...do...	34,650.00	17,325.00
	129	Ransom	11.000	.....do	Feb. 21	50,820.00	25,410.00
	130	Towner	9.000	.....do	...do...	41,580.00	20,790.00
	131	Grand Forks	11.000	.....do	...do...	50,820.00	25,410.00
Oklahoma	40	McCurtain	52.000	Gravel	Feb. 18	781,516.66	390,758.33
	43	Rogers	5.000	Brick and gravel	...do...	100,000.00	50,000.00
South Carolina	45	Richland	7.952	Topsoil	Feb. 12	69,275.01	34,637.50
	59	Berkeley	15.176	Sand-clay	Feb. 26	141,775.59	70,887.79
	76	Pickens	6.130	Topsoil	Feb. 15	90,335.95	22,316.68
	99	Colleton	15.707	Sand-clay	Feb. 7	121,815.21	40,638.08
	127	Aiken	.....	Bridge	Feb. 21	129,530.06	64,765.03
South Dakota	70	Custer	11.830	Earth and gravel	Feb. 8	169,270.20	84,635.10
	71	Hoakon and Zieback	.....	Bridge	Feb. 15	119,373.10	59,686.55
	72	Hoakon	3.494	Gravel	Feb. 24	52,948.83	26,474.41
Texas	227	Titus	20.170	.....do	Feb. 8	209,221.91	104,610.95
	231	Angelina	8.000	.....do	Feb. 21	96,250.00	24,062.50
Vermont	22	Rutland	1.200	Concrete	Feb. 26	47,615.70	23,807.85
Virginia	71	Fairfax	1.920	.....do	Feb. 8	73,539.40	36,769.70
	82	Powhatan	8.010	Topsoil	...do...	51,456.24	25,728.12
	104	Bedford and Roanoke	9.260	Macadam	Feb. 18	357,616.05	178,808.02
	112	Fairfax	2.790	Bituminous macadam	Feb. 8	81,977.50	40,988.75
Wisconsin	127	Dunn	4.050	Concrete	Feb. 7	162,314.68	54,000.00
	135	Buffalo	[2] 1.580	.....do	Feb. 18	[2] 109,974.65	[2] 36,258.22
	194	Columbia	2.040	Gravel	Feb. 26	24,003.98	10,000.00
	208	Grant	1.000	Concrete	Feb. 7	59,544.10	25,000.00
	209	.....do	.570	.....do	Feb. 18	54,564.95	11,000.00
Wyoming	108	Washakie	17.343	Topsoil	Feb. 8	154,385.00	77,192.50

[1] Withdrawn.
[2] Revised statement. Amounts given are increases over those in the original statement.
[3] Revised statement. Amounts given are decreases over those in the original statement.
[4] Decrease in mileage.

PROJECT AGREEMENTS EXECUTED IN FEBRUARY, 1921.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Arkansas	23	Jackson	[2] 3.190	Gravel	Feb. 26	[2] $36,107.10	[2] $20,000.00
	36	Washington	38.800	do	Feb. 5	214,106.22	100,000.00
	50	Phillips		Bituminous concrete	Feb. 21		[2] 20,000.00
	94	Crittenden	9.370	Clay-bound gravel	Feb. 16	105,814.50	40,000.00
	113	Lawrence	2.150	Gravel	do	29,523.34	12,600.00
Colorado	23	Meso		do	Feb. 21	[2] 12,853.25	[2] 6,426.63
	28	Summit		Earth	Feb. 1	[2] 8,199.51	[2] 4,099.75
	47	El Paso	1.748	Gravel	Feb. 21	38,217.41	19,108.70
	68	Rio Grande		do	Feb. 23	[2] 1,874.85	[2] 937.43
	74	Moffat		do	Feb. 21	[2] 4,507.99	[2] 2,254.00
	82	Jefferson		Concrete	Feb. 2	[2] 4,664.47	[2] 1,344.88
	87	Boulder	1.334	do	do	57,970.54	26,680.00
	101	La Plata	4.091	Gravel	Feb. 21	53,073.71	26,536.85
	124	Conijos		Bridge	Feb. 23	14,722.29	7,361.14
	185	Garfield	1.270	Earth	Feb. 21	59,334.83	25,400.00
Florida	17	Manatee	7.870	Brick and concrete	Feb. 1	331,278.00	157,400.00
	17	Manatee		do	Feb. 23	[3] 44,031.84	[3] 13,776.92
Georgia	1	Clayton, Henry, Spalding, Pike, Monroe.	[4] 9.310	Concrete and sand-clay	Feb. 4	[2] 20,420.58	[2] 10,550.46
	8	Montgomery and Wheeler		Concrete and steel bridge	do	[2] 10,525.52	[2] 5,262.76
	18	Dooly		Sand-clay	Feb. 21	[2] 22,486.03	[2] 11,243.01
	44	Hall	[2] 10.631	Concrete	Feb. 25	[2] 115,762.23	[2] 57,881.11
	125	Lee	[2] 8.365	Sand-clay	Feb. 21	[2] 51,053.74	[2] 25,526.87
	134	Coweta	19.850	Topsoil	Feb. 19	251,780.26	65,000.00
	143	Laurens		Reinforced concrete bridge	Feb. 25	133,513.91	66,756.95
	152	Grady		Bridge	do	60,436.07	22,207.03
	153A	Newton	0.900	Sand-clay	Feb. 15	62,336.62	31,168.31
	163	Stewart	1.515	do	Feb. 12	28,634.61	12,500.00
	186	Johnson	3.100	Gravel	Feb. 4	29,447.13	14,723.56
	189	Hart	3.831	Sand-clay	Feb. 25	31,257.43	15,628.71
	196	Early	6.000	Topsoil	Feb. 21	44,552.02	22,276.01
	200	Webster		Bridge	Feb. 25	9,984.02	4,992.01
	204	Lowndes and Echols	5.663	Sand-clay	Feb. 28	33,301.01	16,650.50
Idaho	9	Adams and Idaho	[4] 3.020	Earth	Feb. 1	[2] 70,183.19	[2] 35,091.60
	19A	Bonner	12.569	Broken stone	Feb. 18	166,734.01	83,367.00
	21A	Bonneville	3.863	Bituminous concrete	Feb. 11	175,871.82	80,750.31
	31A	Benewah	8.248	Gravel	Feb. 15	211,293.23	89,098.22
	33B	Nez Perce	2.970	Earth	Feb. 24	68,393.24	34,196.62
	37	Jerome	4.260	Gravel	Jan. 29	94,952.05	47,452.35
	42	Gooding	5.034	Crushed rock	do	53,734.45	26,499.77
	46A	Bonneville	2.042	Bituminous concrete	Feb. 18	53,604.46	40,846.00
	47	Kootenai	8.240	Gravel	Feb. 11	83,200.00	6,600.00
Illinois	15-1	Williamson	5.812	Earth	Feb. 19	76,076.59	19,019.14
	18-2	Champaign	0.379	do	do	63,563.55	15,890.88
	18-5, 6, 7	Champaign and Piatt	2.624	do	Feb. 14	62,750.35	15,687.57
	18-12	Mason	1.508	do	do	19,991.89	4,997.97
	18-20	Sangamon	3.069	do	do	45,712.74	11,293.18
	18-26	do	1.073	do	do	27,379.69	6,844.92
	19-18, 19	Stephenson	2.634	do	do	106,075.03	26,518.75
	20-2 to 8	Henry and Bureau	16.627	do	do	272,635.60	68,158.89
	20-10, 11	Bureau	1.117	do	Feb. 19	28,228.94	7,057.22
	21-2	Warren	0.935	do	Feb. 14	49,092.02	12,273.00
	22-1	Kankakee	0.322	do	do	7,095.04	1,773.76
	23-2	Effingham	1.932	do	Feb. 19	32,342.72	8,085.68
	23-4 to 8	Effingham, Clay, and Wayne	7.504	do	Feb. 14	446,379.17	111,594.77
Iowa	11	Warren	16.260	do	Feb. 24	103,731.43	50,000.00
	38BC	Plymouth	20.842	do	Feb. 10	97,873.27	45,000.00
	53	Louisa	20.840	do	do	131,039.42	65,500.00
	66	Kossuth	23.340	do	do	114,847.97	57,000.00
	75ABC	Marion	13.362	do	Feb. 24	99,406.67	49,000.00
Kansas	94	Hancock	24.349	Brick or concrete	Feb. 27	1,297,552.08	476,600.00
	47	Chase	2.898	Earth	Feb. 23	24,031.34	8,694.00
	48 CHD.	Jefferson	10.742	Bituminous macadam	Feb. 12	706,411.55	95,000.00
	54	Sedgwick	5.599	Bituminous filled brick	Feb. 15	410,584.07	73,950.00
	58	Shawnee	7.965	Earth and brick, concrete or bituminous macadam.	Feb. 8	71,028.63	23,865.00
Louisiana	17	Tangipahoa	[1] 4.910	Sand-clay, gravel	Feb. 24	[1] 65,541.08	[1] 32,770.54
	18	Caldwell	[1] 2.400	do	Feb. 21	[1] 11,462.99	[1] 5,000.00
	29	Franklin	[1] 10.470	do	Feb. 24	[1] 101,635.93	[1] 50,000.00
	43	Calcasieu	[1] 11.790	Gravel and shell	Feb. 27	[1] 245,092.59	[1] 122,546.29
	68	Caddo	[1] 9.500	Macadam base, Kentucky rock asphalt.	Feb. 24	[1] 371,102.72	[1] 185,551.36
	77	Rapides	7.840	Sand-clay	Feb. 14	98,382.62	49,191.31
Maryland	25B	Charles	3.930	Gravel	Feb. 16	49,692.17	24,846.08
	33C	Carroll	2.260	Earth	do	47,746.27	23,873.13
	35A	Washington	0.840	Sheet asphalt	Feb. 10	24,350.04	12,175.02
	41	Garrett	1.990	Graded	Feb. 5	50,292.00	25,146.00
	44	Kent	0.950	Concrete	Feb. 10	38,905.90	19,000.00
	46	Somerset	0.710	Bridge and earth	do	20,918.42	10,459.21
	47	St. Marys	4.440	Gravel	Feb. 16	86,939.90	43,469.95
Michigan	38	St. Clair		Concrete	Feb. 18	[2] 103,140.81	[2] 580.37
	43C	Muskegon	7.929	do	Feb. 15	330,220.96	165,110.48
Minnesota	2	Chisago		Gravel	Feb. 23	[2] 8,639.40	[2] 4,319.70
	25	Stearns		do	Feb. 7	[2] 26,588.83	[2] 16,668.97
	26	Todd		do	Feb. 1	[2] 217.76	[2] 5,377.72
	88	Chippewa		do	Feb. 7		[3] 10,000.00
	95	Chisago		Gravel, brick, bituminous concrete	Feb. 16	[2] 11,269.18	[2] 5,645.56
	122	Chippewa		Gravel	Feb. 1		[2] 10,000.00
	132B	Becker	4.410	do	Feb. 9	40,436.81	13,966.14
	145A	Lac qui Parle	7.060	do	Feb. 1	82,813.77	33,461.84
	147	Houston	18.030	Sand-clay	Feb. 23	325,248.70	150,000.00
	160	Otter Tail	8.440	Gravel	Feb. 18	119,134.15	59,000.00
	194	Lac qui Parle	10.360	do	Feb. 8	30,794.12	10,000.00
	198	do	5.780	do	Feb. 5	14,370.52	5,000.00

[1] Canceled.
[2] Modified agreement. Amounts given are increases over those given in the original agreement.
[3] Modified agreement. Amounts given are decreases over those given in the original agreement.
[4] Decrease in mileage.

206323

PROJECT AGREEMENTS EXECUTED IN FEBRUARY, 1921—Continued.

State.	Project No.	County.	Length in miles.	Type of construction.	Project agreement signed.	Estimated cost.	Federal aid.
Missouri	26	Dunklin		do	Feb. 8	[2] $17,156.50	[2] $8,578.26
	27	Cooper		Bituminous macadam	do	[2] 452.61	[2] 226.30
	30	Morgan		Gravel	do	[2] 242.56	[2] 121.28
	47A	Cedar	9.736	Earth	Feb. 28	43,615.26	21,807.63
	56	Jasper		Concrete	Feb. 8	[2] 2,892.10	[2] 1,446.05
	81	do		do	do	[2] 969.88	[2] 484.94
	83	Jasper and Newton		do	do	[2] 6,675.18	[2] 3,337.59
	84	Jasper		do	do	[2] 3,919.55	[2] 1,959.78
	88	Cedar	7.420	Earth	do	21,479.71	10,739.85
Montana	10	Cascade		Gravel	Feb. 2	[2] 25,249.92	[2] 12,624.96
	22	Ravalli		do	Feb. 19	[2] 10,590.12	[2] 5,295.06
	53A	Yellowstone		do	Feb. 1	[2] 8,258.66	[2] 4,129.33
	61	Wibaux		do	Feb. 2	[2] 8,896.36	[2] 4,448.18
	79	Roosevelt		Bridge	do	18,557.00	9,278.50
	99	Flathead	3.780	Gravel	do	20,411.76	10,205.88
	114	Rosebud		do	Feb. 1	[2] 6,178.80	[2] 3,089.40
	125	Sweet Grass		Bridge	Feb. 16	16,562.15	8,281.07
	129	Stillwater	1.160	Earth	Feb. 10	32,368.36	16,184.18
	134	Yellowstone	3.234	Gravel	Feb. 2	39,484.58	19,742.29
Nebraska	42	Loup		Earth	Feb. 5	[2] 32,061.91	[2] 16,030.96
Nevada	6	White Pine		Gravel	Feb. 1	[2] 11,757.59	[2] 5,878.79
	14	Douglas		do	Feb. 16	[2] 13,770.75	[2] 6,885.37
	29AB	Washoe	0.010	Concrete	do	[2] 41,674.39	[2] 1,942.36
	35	Clark		Bridge	do	7,491.00	3,745.50
New Hampshire	132	Strafford	0.340	Gravel	Feb. 1	9,981.20	4,990.60
North Carolina	58	Johnston		Topsoil	Feb. 5	[2] 1,526.25	[2] 763.13
	71	Durham	[2] 0.022	Concrete base, bituminous top	Feb. 12	[2] 28,823.96	[2] 440.00
	73	Nash	8.729	Topsoil	Feb. 2	159,913.16	79,956.58
	82	Davidson	1.536	do	do	62,454.75	31,227.37
	84B	McDowell	6.125	do	do	109,659.49	54,829.74
	99B	Chatham	21.817	do	Feb. 21	259,931.59	129,965.79
	101A	Randolph	10.040	do	Feb. 12	123,893.99	61,946.99
	107	Madison	2.459	do	do	70,910.40	35,455.20
	117	Wilson	6.251	do	Feb. 12	41,828.93	20,914.46
	127	do	7.629	do	Feb. 15	49,218.94	24,609.47
North Dakota	20	Wells	[2] 0.233	Grading	Feb. 1	[2] 82,258.99	[2] 41,129.50
	36	Barnes		Earth	do	[2] 5,893.58	[2] 2,946.79
	55	Stutsman	5.980	do	do	39,636.33	19,818.16
	59	Richland	14.430	do	Feb. 24	67,135.26	33,567.63
	62	McLean	9.970	do	Feb. 1	72,030.11	36,015.05
	78AB	Divide	10.050	do	Feb. 23	71,110.63	35,555.31
	100	Morton and Burley		Bridge	Feb. 17	[2] 316,871.90	[2] 158,435.95
Oklahoma	9	Leflore		do	Feb. 21	[2] 672.31	[2] 336.16
	10	do		do	do	[2] 19,192.25	[2] 9,596.13
	17	Canadian and Grady		do	do	[2] 6,340.57	[2] 3,170.28
Oregon	48	Harney	10.460	Broken stone	Feb. 14	168,107.50	74,053.75
Pennsylvania	88	Indiana	2.688	Reinforced concrete	Feb. 15	273,512.98	53,760.00
South Carolina	38	Oconee	7.165	Topsoil	Feb. 4	49,714.64	24,857.32
	66	Richland	15.136	Concrete or asphalt concrete	Jan. 31	147,062.71	73,531.35
	88	Anderson	9.019	Topsoil	Feb. 17	45,323.68	22,661.84
South Dakota	1	Coddington		Gravel	Feb. 1	[2] 35,157.90	[2] 17,578.95
	3	Grant		do	do	[2] 58,936.97	[2] 29,468.49
	6	Moody		do	Feb. 5	[2] 4,432.64	[2] 2,216.32
	10	Clark		do	Feb. 1	[2] 53,402.58	[2] 26,701.29
	12	Minnehaha	[2] 0.863	Gravel and concrete	do	[2] 161,729.58	[2] 73,356.55
Tennessee	4	Moore and Bedford		Macadam and gravel	Feb. 11	[2] 87,037.07	[2] 43,518.53
	41B	Knox	12.760	Bituminous macadam	Feb. 8	427,024.76	213,512.38
	43	Shelby		do	Feb. 25	[2] 37,715.42	[2] 14,330.85
Texas	129	Milan	8.710	Gravel	Feb. 21	68,669.06	34,334.53
	161	Limestone	23.370	do	do	390,543.83	59,400.00
	177	Hays	17.050	Earth	do	63,877.89	30,000.00
	180B	San Patricio	15.060	Gravel on shell base	Feb. 14	178,352.58	84,000.00
	191C	Milan	5.710	Gravel	do	33,541.57	16,770.78
	199A	Stephens		Bridge	Feb. 11	77,698.29	38,849.14
Utah	4H	Emery	0.550	Earth	Feb. 15	38,086.77	19,043.38
Vermont	5	Franklin		Water-bound macadam	Feb. 24	[2] 5,382.74	[2] 2,691.37
Virginia	39	Buckingham		Topsoil	Feb. 3	[2] 3,328.95	[2] 1,664.48
	43	Albemarle		Water-bound macadam	Feb. 2	[3] 7,490.23	[3] 3,745.12
	72C	King William	6.400	Topsoil and gravel	Feb. 4	65,939.00	32,969.50
	103	Arlington	1.704	Concrete	do	74,933.52	34,558.94
	108	Henrico	3.260	Bituminous concrete	do	100,308.23	50,154.11
Washington	52	Stevens		Gravel	Feb. 19	[2] 19,541.94	[2] 10,200.00
	68	Grant		Crushed rock	Feb. 15	[2] 3,167.01	[2] 2,000.00
	81	Skamania and Klickitat	0.170	Earth	Feb. 3	29,371.76	3,400.00
	82	Kittitas	1.280	do	Feb. 25	65,414.36	25,600.00
West Virginia	10	Mason	[3] 1.580	Concrete	Feb. 26	[3] 2,817.25	
	47	Wetzel		do	Feb. 9	[2] 8,790.00	[2] 4,395.00
	58B	Pleasants	1.890	Earth	do	27,000.00	6,290.00
	67	Berkeley		Bituminous macadam	Feb. 19	[2] 31,160.00	[2] 15,580.00
	89	Logan	2.460	Earth	Feb. 18	68,931.10	34,465.55
	107A	Morgan	3.710	do	do	44,309.50	22,154.75
Wisconsin	80	Green	1.433	do	Feb. 15	[2] 257,231.67	[2] 77,910.75
	84	Jackson	[2] 0.950	do	do	[2] 16,049.55	[2] 7,130.60
	124	Polk	2.380	do	do	45,060.95	19,060.95
	129	Marinette	7.820	do	Feb. 24	72,020.52	33,332.70
	146	Vilas	5.660	Gravel	Feb. 15	55,296.63	19,000.00
	166	Langlade	7.670	Earth	Feb. 8	54,397.16	19,709.30
	178	Ashland	5.980	Earth and sand-clay	Feb. 19	41,720.14	14,110.07
Wyoming	86	Johnson	[2] 0.152	Selected material	Feb. 8	[2] 6,891.50	[2] 3,445.75
	93	Wasakie		Bridge	do	6,102.25	3,051.12
	99	Goshen	3.270	Selected material	do	142,038.82	71,019.41
	106	Wasakie	2.735	do	do	40,269.46	20,134.73

[1] Canceled.
[2] Modified agreement. Amounts given are increases over those given in the original agreement.
[3] Modified agreement. Amounts given are decreases over those given in the original agreement.
[4] Decrease in mileage.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS.

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets, nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

REPORTS

*Report of the Director of the Office of Public Roads for 1917. 6c.
Report of the Director of the Bureau of Public Roads for 1918.
Report of the Chief of the Bureau of Public Roads for 1919.
Report of the Chief of the Bureau of Public Roads for 1920.

DEPARTMENT BULLETINS.

Dept. Bul.*105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913. 5c.
*136. Highway Bonds. 25c.
220. Road Models.
*230. Oil Mixed Portland Cement Concrete. 10c.
*249. Portland Cement Concrete Pavements for Country Roads. 15c.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
314. Methods for the Examination of Bituminous Road Materials.
347. Methods for the Determination of the Physical Properties of Road-Building Rock.
*348. Relation of Mineral Composition and Rock Structure to the Physical Properties of Road Materials. 10c.
*370. The Results of Physical Tests of Road-Building Rock. 15c.
*373. Brick Roads. 15c.
386. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387. Public Road Mileage and Revenues in the Southern States, 1914.
388. Public Road Mileage and Revenues in the New England States, 1914.
*389. Public Road Mileage and Revenues in the Central, Mountain, and Pacific States, 1914. 15c.
390. Public Road Mileage in the United States, 1914. A Summary.
*393. Economic Surveys of County Highway Improvement. 35c.
407. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
414. Convict Labor for Road Work.
*463. Earth, Sand-Clay, and Gravel Roads. 15c.
532. The Expansion and Contraction of Concrete and Concrete Roads.
*537. The Results of Physical Tests of Road-Building Rock in 1916, including all Compression Tests. 5c.
555. Standard Forms for Specifications, Tests, Reports, and Methods of Sampling for Road Materials.
583. Reports on Experimental Convict Road Camp, Fulton County, Ga.
586. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.
*660. Highway Cost Keeping. 10c.
670. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691. Typical Specifications for Bituminous Road Materials. 15c.
704. Typical Specifications for Nonbituminous Road Materials.
*724. Drainage Methods and Foundations for County Roads. 20c.
*Public Roads, Vol. I, No. 11. Tests of Road-Building Rock in 1918.
*Public Roads, Vol. II, No. 23. Tests of Road-Building Rock in 1919. 15c.

DEPARTMENT CIRCULAR.

No. 94. TNT as a Blasting Explosive.

FARMERS' BULLETINS.

F. B. *338. Macadam Roads 5c.
505. Benefits of Improved Roads.
597. The Road Drag.

* Department supply exhausted.

SEPARATE REPRINTS FROM THE YEARBOOK.

Y. B. Sep. 727. Design of Public Roads.
739. Federal Aid to Highways, 1917.

OFFICE OF PUBLIC ROADS BULLETINS.

Bul. *45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

OFFICE OF PUBLIC ROADS CIRCULARS.

Cir.*89. Progress Report of Experiments with Dust Preventatives, 1907. 5c.
*90. Progress Report of Experiments in Dust Prevention, Road Preservation, and Road Construction, 1908. 5c.
*92. Progress Report of Experiments in Dust Prevention and Road Preservation, 1909. 5c.
*94. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1910. 5c.
*99. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1912. 5c.
*100. Typical Specifications for Fabrication and Erection of Steel Highway Bridges. (1913.) 5c.

OFFICE OF THE SECRETARY CIRCULARS.

Sec. Cir. 49. Motor Vehicle Registrations and Revenues, 1914.
*52. State Highway Mileage and Expenditures to January 1, 1915. 5c.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*65. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Aid Road Act. 5c.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
74. State Highway Mileage and Expenditures for the Calendar Year 1916.
*77. Experimental Roads in the Vicinity of Washington, D. C. 5c.
Public Roads Vol. I, No. 1. Automobile Registrations, Licenses, and Revenues in the United States, 1917.
Vol. I, No. 3. State Highway Mileage and Expenditures in the United States, 1917.
*Vol. I, No. 11. Automobile Registrations, Licenses, and Revenues in the United States, 1918. 15c.
*Vol. II, No. 15. State Highway Mileage and Expenditures in the United States, 1918. 15c.
Public Roads Vol. III, No. 25. Automobile Registrations, Licenses, and Revenues in the U. S. 1919.
Public Roads Vol. III, No. 29. State Highway mileage 1919.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH.

Vol. 5, No. 17, D-2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D-3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D-4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D-6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D-8. Tests of Three Large-Sized Reinforced-Concrete Slabs under Concentrated Loading.
Vol. 10, No. 7, D-13. Toughness of Bituminous Aggregates.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.
Vol. 17, No. 4, D-16. Ultra-Microscopic Examination of Disperse Colloids Present in Bituminous Road Materials.

* Department supply exhausted.

Clemson University
3 1604 011 534 148

DATE DUE

DEMCO, INC. 38-2931